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Studies in Ancient Peruvian Metalworking

A. D. Tushingham, Ursula M. Franklin,
and Christopher Toogood

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History, Technology, and Art
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Studies in Ancient Peruvian Metalworking

An investigation of objects from the Museo Oro del Peru exhibited in Canada in 1976-77 under the title "Gold for the Gods"

A. D. Tushingham, Ursula M. Franklin, and Christopher Toogood

In co-operation with Kent C. Day, Carol Jack, and Elke M. Mutterer

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Introduction

From the very beginning of the negotiations carried on between the Royal Ontario Museum and the representatives of the Mujica Gallo Foundation in Lima to obtain an important loan of artifacts from the Museo Oro del Peru for exhibition in Canada,[1] it had been the hope of both parties that metallurgical and related studies could be carried out on the objects to increase our knowledge of Pre-Columbian — and specifically ancient Peruvian — metalworking. We recognized the tremendous contributions made by earlier workers in the field and most recently those of Professor Heather Lechtman of the Massachusetts Institute of Technology.[2] These studies have received their field research complement in her own work and that of others.[3]

Still, much remained unknown, and the planned exhibition of material which had never been out of the country before appeared to provide a good opportunity for further studies. Sr. Mujica Gallo gave the projected symposium his blessing, and plans were made to transport the collection to Toronto in June 1976 and to hold the symposium within a few weeks of its arrival. Dr. Cyril Smith of the Massachusetts Institute of Technology accepted our invitation to participate (unfortunately, Ms. Lechtman would be in Peru at that time and could not come); Ms. Martha Goodway of the Smithsonian Institution's Conservation Analytical Laboratories was to be present; Dr. Rogger Ravines of the Instituto Nacional de Cultura del Peru in Lima would represent Peruvian archaeological interests; Dr. Ursula Franklin of the Department of Metallurgy and Materials Science in the University of Toronto accepted. These experts, with the Royal Ontario Museum's own Conservation Department staff — particularly Mrs. Carol Jack and Mr. Christopher Toogood — and the director of its Peruvian expedition, Dr. Kent C. Day, promised to provide a fund of knowledge and experience which would guarantee significant results. Finally, the Birks Family Foundation of Montreal — Canada's most noted precious metals and jewellery firm — underwrote the total cost of the symposium (transportaion and living costs for participants, supplies, and publication).

Such well-laid plans, unfortunately, never came to fruition. The material from Lima, on the availability of which the symposium depended, did not arrive in Toronto until the beginning of September, allowing only enough time to make condition reports, carry out necessary conservation, and set up the exhibition. Sr. Mujica Gallo, moreover, rightfully annoyed at destructive sampling of some of his objects while on tour in Europe (without permission being asked or granted), refused to allow us to remove even the smallest of samples from inconspicuous parts of the pieces which had come directly to Toronto from Lima.

These two complications forced a complete re-thinking of the symposium; it was obvious that there was not going to be the opportunity to carry out the tests we had wished to make. Our decision was to "lower our sights" but to

make what studies we could in the time available to us and with the non-destructive methods (microscopic and X-ray investigation, particularly) permitted to us. In fact, this meant that during the two-month sojourn of the exhibition in Toronto, pieces appearing to require conservation were removed from display and, while they were in the laboratory, they were studied closely and frequently photographed and X-rayed. Finally, in the few days after the close of the exhibition, when condition reports were again required, a concerted effort was made to concentrate on a few selected pieces and to answer several specific questions. This rather sporadic and unsatisfactory approach made it impossible for the experts from Cambridge and Washington to participate, although Dr. Ravines was in Toronto for about two weeks. Nevertheless, we feel that some new insights into the metalworking practices of ancient Peru and some new information on the use of some of the items in the collection were forthcoming. The continued support of the Birks Family Foundation enables us to make these available to other workers in the vineyard of Pre-Columbian studies.

The principal author has been given the privilege of presenting the new data but he can take little personal credit for much of the analytical and technical work done. Some of the hypotheses are his own — and his co-workers cannot be held responsible for them — but he presents, essentially, the insights and consensus of Dr. Ursula Franklin and her research assistant, Mrs. Elke Mutterer, of Mr. Christopher Toogood, Mrs. Carol Jack, Mrs. Izabella Block-Bolten, and Ms. Gillian Moir of the ROM's Conservation Department, of Dr. Kent C. Day, and of Dr. Martin W. King, of the Department of Clothing and Textiles at the University of Manitoba, who generously made micromeasurements of thickness on various parts of two objects — the nose ornament (Pl. 75) and the crown (Pl. 55) — while the exhibition was on display in the Winnipeg Art Gallery.

We had thought, originally, that this study would serve as a complement to the *Gold for the Gods* exhibition catalogue[4] and we could easily refer to illustrations and information included in it. Such a procedure, we now realize, would limit the use of this publication on technology almost entirely to those who possessed the *Catalogue*. We have, therefore, decided to treat this publication as a completely independent document, illustrating the objects under discussion even when they have appeared in the original *Catalogue*. In some cases, we can provide better photographs than were available when the *Catalogue* was produced; we can also add detailed photographs and radiographs which constitute part of our evidence for conclusions reached or hypotheses set forth. Some of these photographs are the work of Mr. Leighton Warren, Head Photographer of the Museum, and of Mr. Bill Robertson of his staff; many are the result of Mr. Toogood's recording camera, documenting pieces which he studied on various occasions as the conservator chiefly responsible for the condition of the metal objects while they were in Canada; Mrs. Mutterer, as research assistant to Dr. Franklin, was responsible for the radiographs and much of the technical analysis.

Finally, to facilitate cross-reference and identification of the pieces, we have in each instance given the number of the object in the *Gold for the Gods*

catalogue and the registration number assigned in the official Museo Oro del Peru catalogue.[5] This publication will, we hope, complement both of these catalogues. We have had second thoughts not only on metallurgical and technological matters but even on the use to which some enigmatic pieces may have been put; we have not always been able to go beyond an expression of doubt as to the usual ascription but, as every scientist knows, doubt may well be the first necessary step towards understanding.

Before proceeding, it is necessary to describe the types of examination we were able to make. Our tests, when non-destructive, were carried out on the objects themselves as occasion offered and when some visible feature seemed to warrant them. Other tests, both destructive and non-destructive (to ascertain chemical composition and microstructure) were performed on fragments which had become detached during shipment from Lima to Toronto. As the objects had been packaged separately before being fitted into the shipping boxes, the fragments were obviously intrinsic pieces of the object with which they were packaged and offered prime evidence for that object. Likewise, a few other fragments became accidentally detached while the exhibition was travelling in Canada and, because of the packing method used, could be studied to give direct evidence on an object which otherwise could not be tested.

The following research techniques were employed:

Radiography A standard medical X-ray unit capable of voltages up to 150 KV was used. Although there are some constraints on this technique, because of the high gold content of the metal surfaces, we found it more informative than originally expected.

Thickness measurements Using precision micrometers (and lens paper to protect the object from being scratched) we determined the thickness of the samples. Quite a few measurements were made in order to provide the range of variation and to give us confidence in the validity of our averages.

X-ray diffraction Corrosion products were studied by X-ray diffraction, using a 117 mm powder camera and filtered Cu-radiation. If needed, diffraction samples could be subsequently analysed by neutron activation. All patterns could be identified, using the "Powder Diffraction File".[6]

X-ray fluorescence analysis This non-destructive technique was used on a few larger samples. We were again mindful of the effect of the high concentrations of gold in the surfaces; nevertheless, it was not difficult to detect arsenic in all the alloys.

Neutron activation analysis This technique can provide the elemental composition of a sample. This was one of our most useful techniques for very small fragments. The samples required were 10 mg or less; they were analysed in solution using the University of Toronto "Slowpoke" reactor.[7]

Metallographic studies Examinations of prepared microsections were carried out on both unetched and etched section surfaces, using an optical and a scanning electron microscope. The latter was equipped with an EDAX non-dispensive elemental analysis attachment. The most informative optical

studies were actually the carefully conducted direct observations of the objects at lower magnification, using a stereo microscope with a large focal depth.

We do not feel it is necessary to summarize here the current understanding of Peruvian metallurgy. Professor Lechtman has shown how alloys with gold and silver surfaces could be produced by depletion gilding. We would like to emphasize, only, that our results are not inconsistent with the type of processes she has suggested.[8] For instance, our neutron activation data on fragments from 10 objects, extending in date from Vicus to Chimu, showed the presence of gold, silver, and arsenical copper in all of them. In the microsection of one of them — the Chimu "breastplate" (Pl. 2, *Cat.* 150, Reg. 46) — we saw the typical layer sequence indicating hammering, annealing, and changes in surface composition. Microprobe analysis of this sample proved the presence of gold throughout the whole cross-section as well as gold enrichment on the surface. This particular object, then, could have been fashioned by depletion gilding. The almost identical bulk composition of all 10 samples seemed to us an indication that the remaining specimens, too, *could* have been fashioned in this manner.

Further, we found silver nitrate in fragments accidentally detached from the Vicus mask (Pl. 1, *Cat.* 53, Reg. 1226), the Chimu "breastplate" referred to above, and the Chimu (Lambayeque) crown (Pl. 3, *Cat.* 228, Reg. 2881), which suggests that a chemical reaction involving saltpetre could have been used to dissolve the silver in the surface layer of the alloy.

The evidence at our disposal is, admittedly, circumstantial but supports our hypothesis that the depletion gilding technique was in use as early as the Vicus period, extended down through the Mochica and Chimu cultures, and probably continued in use in the Inca period.[9]

We shall, therefore, assume that the metallurgists possessed the skills revealed by these studies and shall produce chiefly examples of the high standards achievable using what appear, to us at least, to be slow and tedious methods.

The evidence from our observations and tests falls essentially into two broad groups: (1) information related to the metal itself and (2) information on the objects made from the metal. The former comprises the intrinsic properties of the sheet or plate and thoughts on how these qualities were obtained. The latter encompasses evidence on techniques used in fashioning and decorating objects, such as methods of joining or fastening, cutting, embossing, and shaping. One result of a comparison of the techniques used in the metalworking and the fabrication processes has been the recognition of the disparity which often appears to exist between them. The metalworking process is highly sophisticated; it yields very thin and uniform sheets of a copper base alloy with a surface enrichment of silver and/or gold. Implicit in these techniques is the mastery of alloying and of chemical and/or thermal surface treatment.

The fashioning of the objects, on the other hand, often relies on simple, mechanical methods and rarely utilizes the metallurgical skills mentioned above. The fabricators often employed techniques borrowed from other

crafts with which they were well acquainted and it is not surprising that those borrowings were mainly from those crafts in which the ancient Peruvians excelled — pottery and weaving. Our examples will, we believe, demonstrate the truth of this general statement. They will also raise, and perhaps answer, the great question of why the Peruvian metalworkers, who so early discovered sophisticated metallurgical processes, appear to have been inconsistent in using, or slow in developing, methods of fabrication and joining of a similar level of competence. Specifically, we must seek an answer to an apparent enigma — the scanty and sporadic evidence for a knowledge of the techniques of welding, soldering, and casting in Peru through the long epoch covered by the Mochica and Chimu cultures as compared with the clear evidence for their use in neighbouring areas such as Ecuador and Colombia, from where they passed through the Isthmus to Maya and Aztec Central America.

A. D. Tushingham

The Metal: Sheet, Plate, and Casting

Metalwork in ancient Peru was essentially a matter of cutting and manipulating two-dimensional sheets to produce the objects and forms desired. The sheet is invariably thin, as we shall see. The large circular discs (*Cat.* 5, 6; Reg. 4011, 4012) are of heavier gauge and are dealt with here as "plate". Looking at the total assembly of objects, we were impressed by the abundant, almost commonplace, use of thin sheet as "raw material". Whether it was formed into crowns, nose ornaments and ceremonial knives *(tumis)*, or into tiny discs or rectangles to be used as pendants or sewn onto textiles, the sheet was handled as if it were readily available and in no way special.

If we concede the quantity of gold- or silver-coloured sheet available, can we say anything about the quality and mode of production of the sheet? Our first task was to measure the thickness of the sheet, a rather simple and inexpensive (as well as non-destructive) procedure which, surprisingly, had apparently not been carried out before. Using our thickness measurements and radiography, we became aware that the thin alloy sheet, the artisan's "raw material", was itself evidence of extraordinary metallurgical competence. Table 1 provides a summary of the results of the thickness measurements (including the disc — *Cat.* 5, Reg. 4011 — which we consider "plate" rather than "sheet") while all details of the taking of those measurements and the objects studied are given in Appendix A.

Evidence of a different but no less graphic kind is provided by the "breastplate" (Pl. 2, *Cat.* 150, Reg. 46). The direct measurement of the thickness of the metal on a cross-section was 0.12 mm. The two photomicrographs (Pl. 4 and 5), the former under magnification of 125× and the other of 300×, show the layered microstructure of the sheet resulting from the manufacturing process.

We are struck by the uniformly fine tolerance in thickness of sheet demonstrated by all the measurements taken. Thickness varies so slightly within one sample of sheet that it compares very favourably with the standards achieved with modern machine tools. Furthermore, because the examples cited span a period of some 1,500 years (from Vicus to Chimu), it is clear that the skill of the ancient Peruvian metalworker must have been developed over a long period preceding the Vicus era. In fact, the skill in sheet manufacture may be traced back another 1,500 or 2,000 years. The tiny fragments of thin gold foil discovered by Dr. Grossman[10] appear to take the technique back at least to the middle of the second millennium B.C. in the south-central highlands of Peru. His comment is graphic enough: "All of the foil was so thin that I was unable to measure its thickness with the equipment at hand."

We may well inquire more closely into the technique by which such accuracy was attained. While the depletion gilding technique requires a sequence of hammering, annealing, and chemical reactions on the surface

Table 1 Summary of thickness measurements

Object	*Cat.*	*Reg.*	*Thickness in mm*		*Number and location of measurements*
			Mean	Stand. Dev.	
1. Disc	5	4011	2.75	0.15	Nine measurements along rim, 0.5 cm from edge
			1.65	0.12	Nine measurements along rim, 2.0 cm from edge
2. Diadem	73	2900	0.12	0.01	Fifteen measurements on upper edge, arc A-B
			0.12	0.01	Eleven measurements on lower edge, arc A-B
			0.11	0.01	Eight measurements on upper edge, arc C-D
			0.13	0.01	Eight measurements on lower edge, arc C-D
			0.15	0.02	Seven measurements on plume
3. Helmet	133	4264	0.10	0.01	Five gold foil rectangles secured to cane structure of helmet
4. Poncho	136	1906	0.09	0.02	Seven gold foil rectangles on poncho
5. Crown	159	3061	0.39	0.03	Eight measurements on upper rim
			0.28	0.02	Eight measurements on lower rim
			0.12	0.02	Eight measurements at waist

Note: see also nose ornaments (*Cat.* 42, 45; Reg. 3361, 3362) in Appendix B.

(with mild acids such as uric and acetic at an early stage and more corrosive substances at the final stage when the silver is removed to leave the gold), there is absolutely no evidence left on the surface of the gold sheet of such hammering or other similar mechanical action. That, in fact, hammering treatment took place is demonstrated by a study of the microstructure of the metal sheet, but no indentations from hammer strokes, or ripple marks which would have resulted from the use of rollers, remain visible to the human eye nor do they, as we have seen, appear to contribute in any obvious way to the slight variations in thickness we have noted above. Is it possible that some rocker system was used, in addition to — or perhaps preceding — the hammering stage?

Petersen[11] illustrates several sets of large stone tools for crushing ore, some of them still used by native miners. One set, in particular,[12] consists of a pair of stones, each with one flat side, which fit together one upon the other. Possibly a mechanism like this could be used to fashion the metal into flat sheets. On the other hand, *batanes*, the large flat stone slabs,[13] and *chungas*, the boat-shaped rocker stones commonly associated with food preparation, are reported to have been used in the working of metal. Perhaps such stones were left in the direct sunshine to become hot (uncomfortably hot to the touch by noon in summer) and this solar heat would serve to keep the alloy at a comparatively elevated temperature for longer periods while the manipulation of the stones gradually thinned the sheet. In our attempts to understand the techniques of the early Peruvian craftsmen and their possible dependence upon local conditions of which we have had no direct experience, we should not allow our imaginations to be cramped by our own technological history where the heat necessary for chemical and other processes has been provided by the combustion of wood, charcoal, peat, coal, and other fossil fuels. It is obvious that we are still far from understanding completely the techniques of the early Peruvian metallurgists, who had a shortage of such fuels but had other materials and facilities at their disposal which we have not sufficiently recognized or evaluated.

Before leaving the matter of sheet metal production, we should consider the technology involved in the large discs, of which some 25 to 30 belong to the Museo Oro del Peru in Lima and from which we chose two (*Cat.* 5, Reg. 4011; Pl. 6, *Cat.* 6, Reg. 4012) for display in the Canadian exhibition. They are not unique or eccentric occurrences, although they do appear to be quite early (Vicus culture). The observable presence of gold, silver, and copper on all of the discs is, we believe, strong circumstantial evidence that they are a result of the technique of depletion gilding and that both surfaces could have been originally burnished gold.

The disc here studied is number 5 of the *Catalogue* (Reg. 4011), which has a diameter of almost exactly 36.6 cm (see Table 1 and Appendix A1). Around the perimeter there is a flat rim slightly more than 0.5 cm wide which is not separated by any sharp line of demarcation from the slightly thinner metal towards the centre.

It is quite obvious that these plates are neither ingots[14] nor sheet metal — their regularity of form and their thickness are against such interpretations.

Unlike the sheet, also, the radiograph (Pl. 7) shows quite clearly the hammer marks used to form the disc. The very accurate degree of circularity in these discs is noteworthy. While we shall notice the same phenomenon when we come to the fabrication of discs from sheet metal or foil, the technique of producing the result here is quite different. Close examination suggests that the discs, once hammered to the desired thickness, were given their form by first cutting with a chisel and, finally, by "corking" — the hammering of the edge back into itself (not folding it over) — which produced the smooth thickened rim we have noted above. This technique was also used, as we shall see, on beakers and other similar vessels produced by raising.

The two or three holes present on each disc (sometimes with traces of the cord or textile used for suspension), the shape, size, and burnishing of both gold surfaces of the discs, and the number of such discs preserved — all these factors strongly suggest that they were intended to be hung about important buildings to catch and reflect the sunshine. Such mirrors, made to serve an architectural purpose, may find their parallel in the later Inca practice of decorating buildings with sheet gold.[15]

There can be little doubt that casting of gold, silver, and copper alloys in moulds occurred in Inca times. The mace head (Pl. 13, *Cat.* 271, Reg. 2054), the balance beam (Pl. 14, *Cat.* 270, Reg. 3311), and, probably, the little lame male figure (Pl. 15, *Cat.* 264, Reg. 3218) are all good examples of the art in this period. The cast silver bells with anthropomorphic features now strung on a necklace (Pl. 16, *Cat.* 349, Reg. 433) probably belong to the same period. But evidence from Peru for earlier periods is conspicuously lacking. One exception to this rule seemed to be the ear-cleaners (Pl. 17, *Cat.* 125, 126; Reg 2305, 4823) which were ascribed to the Nazca culture on the basis of the Museo Oro del Peru register. Such an ascription appeared to be anachronistic, for the few parallels were dated to "Late Chimu".[16] The problem was solved when Sr. Miguel Mujica Gallo, while in Toronto, informed us that the objects came from the Nazca *region* on the south coast but did not necessarily represent products of the *culture* usually denominated as "Nazca"; they can, therefore, be safely ascribed to the late Chimu or Inca period.

The Fabrication of Objects: Shaping and Joining

Under this heading we shall consider the evidence for a variety of ways of manipulating the sheet metal (cutting, embossing, bending, raising, forging (?), and punching) and give the results of our observation on the subject of joining, that is, mechanical and other methods used to fasten one piece of metal to another.

Cutting

We have already observed that the outer edge of the large discs — now thought to be mirrors — was shaped by chiselling before it was finished by corking. One object in the loan collection which received very close study from the point of view of cutting was the arc-shaped piece with openwork and embossed ornamentation (Pl. 18, *Cat.* 231, Reg. 2714). This piece originally formed the upper edge of an ornament similar to the "standard" (Pl. 19, *Cat.* 244, Reg. 2879). A detail photograph (Pl. 20) and a radiograph (Pl. 21) reveal the uniformity of cut-out ornament and suggest strongly the use of a template. Perhaps the most obvious feature, however, is the crudity of the cutting which could result only from the somewhat inept use of a chisel with a narrow blade (perhaps of arsenical copper) which was not followed up by any attempt to smooth away jagged edges and sharp wiry projections.

An apparent lack of concern for a neat finish is also to be seen in the crown (Pl. 55, *Cat.* 159, Reg. 3061). Before the sheet was made into a waisted cylinder and the ends "laced" together, the ornamentation was embossed. The embossing of the lower half consists of two rows of small punched bosses with another pair about 7 cm above. Of the four rows, the lower three are worked from inside, that is, the bosses project outward. The fourth row, like all the embossing in the upper zone (the two rows of rectangular panels alternately filled with stylized birds in reserve against a punched background), is applied from the outside. We would expect another row, or perhaps even two rows of similar punched ornament as an upper border for the crown. One of the other waisted crowns in the collection (Pl. 58, *Cat.* 161, Reg. 2215) provides an interesting parallel;[17] it, too, is ornamented with horizontal lines of punch-marks and zoomorphic and bird motifs in reserve against a punched field — all the punching worked from the outside. Unlike *Catalogue* 159, however, the crown (*Cat.* 161) appears to be complete, that is, the borders marking the upper and lower edges are fully preserved. When to this evidence we add the observation that the upper edge of *Catalogue* 159 has been left very ragged, we are forced to conclude that for some reason the upper edge of *Catalogue* 159 was crudely cut to such an extent that not only was the upper border removed but the upper edges of the punched rectangles were pared. It is

possible, of course, that such poorly finished work was concealed by some other ornament such as feathers, but the fact remains that, in some cases at least, the Peruvian craftsman (and presumably his employer also) was not disturbed by such crudity of finish.

A close inspection of the detail of the waisted crown (Pl. 56, *Cat.* 159, Reg. 3061) reveals the lines which have obviously been scribed to guide the craftsman in his application of the embossing. They can also be seen on the reverse of the "breastplate" (Pl. 22, *Cat.* 150, Reg. 46).[18] Although traces of such lines can be seen along the edges and around the cut-out ornament of the arc-shaped piece (Pl. 20, *Cat.* 231, Reg. 2714), and must have formed a guide to the workman cutting the arc, it is just as clear that the line does not form an arc of a perfect circle. The "mirror" discs, already referred to, suggest in their form the use of a device for describing a circle (the equivalent of a modern compass) which may have consisted of a cord with one fixed end and a scriber at the other end. The neat concentricity of the panels of decoration in the silver shield cover (?) (Pl. 23, *Cat.* 246, Reg. 4841) also suggests the use of a compass-like device, but the evidence is certainly not sufficient to go further than the mere suggestion.

The use of templates indicates mass production for cutting (and shaping, see below), and there is further evidence for this. It is difficult to escape the conclusion that a profusion of templates was available to provide the consistency in layout (if not in actual cutting) so evident in the gold ornament now sewn to the child's poncho (Pl. 24, *Cat.* 238, Reg. 4114), the cloth bag (Pl. 25, *Cat.* 74, Reg. 4132), and the frieze of monkey plaques now attached to the textile (Pl. 26, *Cat.* 134, unregistered). We should also note that the tiny gold plates with three holes which are sewn to the poncho (Pl. 12, *Cat.* 136, Reg. 1906) appear to have been used also to cover the reed or cane structure of the hemispherical caps or helmets (Pl. 10, *Cat.* 133, Reg. 4264). One can visualize a division of labour, in which the fine sheet was made by one group of craftsmen; the thousands of discs, platelets, and other ornamental forms were made by another group; and the final assembly of these elements with basic forms such as masks, helmets, ear-rings, and textile articles of one kind and another, was the work of a third group.

Similar evidence of mass production can be seen in the manufacture of turquoise and chrysocolla beads; the fact that the same forms — almost invariably drilled with holes presumably for stringing — are used in beads and to enhance other objects to which they are not sewn but are, apparently, secured with some adhesive, suggests that one group of workers spent its time producing quantities of beads while another group or groups used them as required for a variety of purposes (note, for instance, the pierced bead forms used in Pl. 27, *Cat.* 162, Reg. 4652; as beads and inlay in the *tumi* of Pl. 79, *Cat.* 227, Reg. 2708; in the necklace of Pl. 28, *Cat.* 304, Reg. 464; and a host of other examples).[19]

Stamping

One of the commonest forms of ornament in Peru was the application to almost every type of object of a multitude of small gold discs, lunates,

crescents, ovoid and drop shapes, stylized birds, human masks, bell, and floret forms. Although these shapes vary in size, the existence of a quantity of each form in one size or in a restricted number of sizes may demonstrate the possibility of sets of dies for stamping out such forms in quantity. Compared with templates which, as patterns, merely established an outline which could then be cut out with chisels, the smaller and less ornate forms we are discussing here may have been cut from the sheet using hollow tubular punches with bevelled cutting edges.

We recognize that there are several difficulties in assuming that such tools were used. As far as we could see, the gilt surface of these tiny discs and other ornaments covered the edges as well as the flat or slightly curved faces of the pieces. At first, we felt that this gilding on the edges could have been produced only by a final pickling and burnishing on each small ornament after it was cut out; if so, the very smoothness of the edges of the discs and other ornaments could also be a result of this retouching process and not require the use of a punch (as distinct from a chisel which would leave an uneven line). The answer is probably much simpler. The thickness of the sheet is so minimal (see Table 1 for the thickness of the small rectangular plates on the poncho and the helmet — amounting to an average of approximately 0.1 mm) that the very cutting by the punch would pull enough of the gold surface down with it to seal the edge of the ornament.

A far more serious difficulty is the fact that the slight burring and curvature which we would expect at the edge of such discs and other shapes as a result of the pressure of the punch cannot be detected. Because most of these discs and similar forms are almost paper-thin and, in many cases, are slightly bossed, marks from a hollow punch might be difficult to see, but the discs ornamenting the mask (Pl. 29, *Cat.* 57, Reg. 3772) are somewhat thicker (making the cutting by punch much more difficult) and quite flat. It seems rather unlikely that each shape was cut out by chisel and then laboriously smoothed. We can, at the moment, only point out these facts. To our knowledge, no punches or other similar instruments for cutting sheet metal or foil are reported in the archaeological record but they may, of course, be found, or recognized, at any time.

Embossing

Embossing was the commonest technique used to give ornamental relief, and strength, to the comparatively thin sheet metal. The "breastplate" (Pl. 2, *Cat.* 150, Reg. 46) for instance, is covered with two sizes of circular boss, one approximately 1 cm in diameter, the other approximately 2 mm in diameter. We have already noted that the thickness of the metal in this "breastplate" was about 0.1 mm; obviously it had little inherent strength and would hardly withstand blows or, if purely "parade" armour, would hardly hold its shape without some additional treatment. Embossing could provide some rigidity as well as surface ornamentation to the material. Apparently the smaller bosses were made first, because a few of the larger bosses impinge upon the smaller ones (Pl. 30 and 31). As we have seen,

lines scribed on the back of the sheet (Pl. 22) were used as a guide for the placing of the bosses and have cut through the bright gold surface of the sheet and exposed the underlying darker core metal. The overlapping of the small and large bosses and this ruthless cutting through the fine gold surface of the sheet (especially on what must have been a piece of royal equipment used on ceremonial occasions) suggest strongly that this stage of ornamentation was the work of a fabricator, not of the metallurgist who produced the sheet originally. The fact that the guide lines are on the reverse side of the sheet also demonstrates that the bosses are *en repoussé*, that is, formed from the reverse side by pushing the metal into a die held against the outer face of the metal. To give each large boss a sharp, precise outline, a further step was taken: a tubular punch of the same diameter as the boss was fitted over the outer perimeter of the boss and tapped lightly. The resultant lines are quite clear (Pl. 30 and 31).

The same photographs show that the larger bosses were made by multiple (12 to 15) strokes of an instrument with a rounded end, of about the same diameter as that of the punch used for the smaller bosses. While, no doubt, the ends of these tools were usually rounded — to produce, at one blow, a hemispherical boss — there is evidence that they could be given other forms to produce such effects as those on the nose ornaments (*Cat.* 27, Reg. 3564; Pl. 32, *Cat.* 28, Reg. 3565) and the "wrist guard" (Pl. 33, *Cat.* 131, Reg. 3238).

Such embossing as we have described so far is comparatively simple, even though the difficulty of working already thin metal into dies,[20] or forcing it with punches, without at the same time rupturing the sheet, must have been considerable. The difficulty would, of course, be increased by the fact that the metal was not pure gold, silver, or copper but an alloy of two or three of these which must have been far less ductile than pure metal. The creation of the mask on the nose ornament (Pl. 75) over a welded joint between a sheet of gold and a sheet of silver was, without doubt, a *tour de force;* that it was not wholly a success is not surprising. Similar challenges faced the craftsman of the rattle (Pl. 34 and 35, *Cat.* 116, Reg. 265). As we have it now, the sheet metal of the "blade" portion of the ornament is very thin and friable; that this is not simply a result of surface corrosion is demonstrated by the fact that the original red and blue paint still adheres to the surface in several places. Close examination shows that the metal of the upper part of the rattle — that which was deeply embossed — was thicker than that of the "blade" but, even so, the craftsman faced formidable problems: to produce from a single sheet an object consisting of a flat mirror with a shiny gold surface in the form of an axe-blade with flaring sides, ornamented at the top with an elegant cluster of six gourd forms (the actual rattles) in the round, and incorporating three horizontal tubular elements which formed part of the hinge by which the rattle could swing freely. This masterpiece of the ancient Peruvian metalworker's art reveals careful planning in advance. The design of blade and gourd forms constitutes an aesthetic whole. The blade was hammered to paper thinness and the gourd forms were embossed and chased in two parts which would fit together exactly when the ultimate — and most difficult — stage was reached: the bending of the upper section of embossed thin metal through 180 degrees so that the gourd and hinge forms

(front and back) would line up exactly. It seems obvious, also, that the art of local annealing had been mastered, that is, the craftsman could repeatedly heat, and restore ductility to, the part of the object which he had to emboss very deeply and finally bend through 180 degrees while, at the same time, he could preserve the temper and finish of the very thin mirror portion. Incidentally, our identification of this piece in the *Catalogue* as a rattle is probably correct, but this simple statement falls short of describing its purpose and use. Such an object appears to have formed part of the dress of warriors (see, for example, the ear spools of Pl. 36, *Cat.* 105, 106; Reg. 4922, 4923, themselves masterpieces of the embosser's art), secured to the belt at the back so that every movement of the wearer would cause it to flash in the sun and rattle at the same time — not too far a cry from the perennial masculine (and particularly military) delight in the gleam of polished brass and leather, and the clink and rattle of chain-mail epaulettes, spurs, and horse-trappings.

These remarkable pieces, however, must be seen in a context of a common practice of deep embossing in thin sheet metal whose chief product was a profusion of hollow beads of various sizes and forms (spherical, ellipsoid, ovoid, pillow-shaped, and biconical). All are manufactured in the same way: two identical halves (hemispheres to produce spherical beads) were formed by pressing or tapping gold sheet into a deep die, or by shaping over a wooden mould, a feat of no mean skill when one considers the thinness of the sheet and that the sheet itself was a somewhat intractable alloy, not pure gold. The two halves were then forced together with, at the most, some organic adhesive to strengthen a joint which is essentially mechanical. There is no evidence of solder or welding on these beads (Pl. 37 and 38, photograph and radiograph of necklace *Cat.* 323, Reg. 1628). Some beads are even more complex. The necklace (Pl. 39 and 40, *Cat.* 293, Reg. 2049) consists of a series of graduated hollow beads in the form of fish vertebrae, now re-strung in a double strand. Each bead is cleverly fashioned from at least four small sheets, the longitudinal pieces being waisted and shaped by embossing to provide sufficient strength to maintain the form; they are joined, it appears, by simple pressure, perhaps with some organic adhesive inserted. The hourglass-shaped sections are joined to round end-plates by little tabs (see below).

Our references to dies or forms in which, or over which, thin sheet could be worked to provide the forms so characteristic of ancient Peruvian gold-work ornament leads us to make a comment on two pieces illustrated in the *Catalogue* (Pl. 41, *Cat.* 362, 363; Reg. 1198, 1207) as possible examples of such dies. We noted there that the stone mould with the florets on the two surfaces was — if used as a die — certainly no earlier than Colonial times. On the other hand, we suggested that the mould section might be Pre-Colonial for we interpreted the motif represented as that of a monkey. While this mould was in Toronto we were able to make a reproduction from it in plasticine. The resulting cast is not a monkey mask but a "classical" knop in the form of a bud with tight petals, presumably used as the terminal or finial of a rod, a baluster, or something similar. In any case, this form of ornament is Colonial — like the florets of the stone mould — and cannot

prove that similar moulds or dies were used in Pre-Colonial times for metal. We must return to this question below, however.

Hammering and Shaping

As we have seen, the evidence for the shaping of precious metals in Peru by casting before late Chimu or Inca times is exceedingly slight. However, there was a technique, using sheet, which produced essentially solid objects. A copper needle from the ROM Peruvian collections was submitted for examination and displayed a microstructure which is compatible with a process of manufacture in which a very thin hammered sheet of an alloy of arsenical copper was rolled into a tight elongated rod, more or less round in section, which was then hammered and annealed to form a serviceable tool (Pl. 42a, b). Much the same process seems to have been used to produce the gold needles (Pl. 43, *Cat.* 67, 68; Reg. 2407, 2408) shown in Toronto.

The enigmatic objects (Pl. 44, *Cat.* 196, 197; Reg. 2970, 2971) which were labelled spindles in the *Catalogue*, were so identified for want of a better hypothesis as to their use and because this was the term applied to them in the Museo Oro del Peru catalogue. They remain a puzzle, both as to use and manufacture, but it seems impossible to consider them spindles. They measure 17.5 and 17.3 cm in length, respectively; the spatulate ends are solid, but the mid-section is hollow with a single hole opening to the surface (Pl. 45, radiograph of *Cat.* 196); although the radiograph appears to show this hole as penetrating through the object, this is not a fact. The hole is about 9.0 mm deep and runs in diagonally. A wire inserted into the hole shows that the hollow section extends about 2.5 mm on one side of the hole and 5.0 mm on the other, giving an approximate length for the hollow of 7.5 mm. Remains of a white deposit were found in it but there was not enough for analysis. It may have been some sort of resin. There are hammer-marks along the object and, in particular, two hammered seams parallel to the length of the object are quite clear under the microscope, the more pronounced one on the side opposite the hole. In fact, the object seems to have been made out of two pieces of sheet, of a width equal to the largest circumference of the spindle, hammered together. It seems probable, therefore, that a small quantity of some substance was rolled up in the two sheets at the point where the hollow was desired and, after the beating of the sheets together, the substance was removed through the hole. At present, no really acceptable use for these objects has been proposed. They could have been used as toggle pins (the precursor of "safety-pin" fibulae, buttons, and zippers) secured by a cross-stitching at the thickened section to one part of the garment while cords or loops on the other part of the garment were wound around or slipped over them to hold the two parts of the garment together. If this interpretation is correct, the hole's only use was to remove the assumed substance from the thick central section of the pin and served no other purpose.

It is possible that the gold spatulas and gravers (Pl. 46, *Cat.* 69, 70, 71, 72; Reg. 2411, 2412, 2413, 2414) were formed in the same way as the "spindles" just discussed but, of course, without the central swelling. The spatulas and gravers have not been carefully examined.

Raising

The Peruvian craftsman developed the technique of raising at least as early as Vicus times and used it throughout all the succeeding centuries down to the Inca period. His main products, using this process, were bowls, beaker cups, and jars. To produce these objects he used sheet of a greater thickness than that used for many of the other ornaments — and especially for the foil appliqués on textiles. This fact can be demonstrated quite clearly from the thickness of the bases of the vessels which represent the original thickness of the metal. Starting at the base, the sheet was hammered over a horizontal arm or stake, being turned constantly so that the metal was forced outward and upward from the base. If the sheet were a copper-silver-gold or copper-gold alloy, repeated heating, annealing, and pickling would permit the gradual thinning of the metal and, at the same time, produce or preserve the gold surface desired. When the process was complete, the upper edge was "corked", that is, hammered back into itself to give a somewhat thicker, stronger, edge which was smooth to the touch. The thickness of the sheet, therefore, was greatest in the base and at the rim, while least in the area immediately above the base (for example, Pl. 47, 48, and 49; *Cat.* 95, 146, 151; Reg. 4561, 4585, 4631). The embossing of such pieces and the application of other ornament can be seen in Plate 50 (*Cat.* 148, Reg. 4608) and Plate 51 (a detail), while the double base (the lower section holding a stone or seed to make it a rattle) with its simple mechanical joint is shown in Plate 52.

While the most obvious products of the raising technique are open-mouthed vessels, it could be used in what appear to be closed vessels. The jar (Pl. 53, *Cat.* 205, Reg. 4630) is a good example of this. This double-spouted, bridge-handled jar imitates in metal a pottery form very common in Mochica and Chimu times. The body consists of two sections, both probably raised, joined along their greatest circumference which becomes a sharp carination. The join is a simple matter of overlapping the metal and crimping it (Pl. 54); in practice, however, as Mr. Toogood has pointed out, the successful and neat crimping of these two forms together would probably require local annealing, to ensure a tight, smooth join, and an inner support against which the craftsman could exert pressure in the bending of the metal. The jar was not examined closely enough, nor radiographed, so we do not know whether, at the time of the crimping, the top or bottom of the jar was open or whether the support was inserted through one of the holes now concealed by the bridge handle.

A technique, at least resembling raising, has probably also been used to produce the waisted crowns. While crowns, or head-dresses with straight sides do occur (Pl. 3, *Cat.* 228, Reg. 2881), the commoner form appears to have a slight constriction which gives it an hourglass appearance. Three crowns of this type appeared in the Canadian exhibition (Pl. 55, 56, and 57, *Cat.* 159, Reg. 3061; Pl. 58, *Cat.* 161, Reg. 2215; *Cat.* 235, Reg. 1651). The waisted form has a very practical advantage in that it fits the head firmly, sliding down until the waisted part comes to rest against the head. It may also be influenced by head-dresses made of feathers mounted on textile backing which sometimes have the same waisted form. The close study of

Catalogue 159, to discover how the form was produced in metal produced some interesting results.

Mr. Toogood, of the ROM staff, who is a trained metalworker, noted that the logical way to produce such a form from a sheet of metal would be, first, to cut a rectangular piece of sheet of a width roughly equal to the height desired for the crown and a length equal to a little more than the circumference of the cylinder at the waist. This sheet would be formed into a cylinder by overlapping and joining the ends. With the cylinder slipped over and supported on a horizontal stake, the craftsman would hammer and stretch the edges so that their circumference would be increased relative to the circumference of the waist. One consequence of this procedure would be that the metal in the crown would be thicker at the waist than at the upper and lower edges.

It is, however, obvious that this is not the technique used by the ancient Peruvian craftsman. The cylinder was not created at the beginning, but at the end of the process. The evidence for this is clear:

1. There is no indication of any hammering on the overlap of the two ends of sheet; the joint, therefore, followed the shaping process.
2. Along the upper edge of the crown, the thickness of the metal averages 0.0153 in., along the lower edge 0.0111 in., but at the waist only 0.0049 in. (Table 1, no. 5). The metal is, therefore, thinner at the waist, not thicker as would be the result of the technique of manufacture just described.

Mr. Toogood has experimented with another technique which has produced the results desired, that is, a waisted cylinder of gold-coloured sheet in which the thickness of the sheet at the waist is substantially less than that at the upper and lower edges.

For his experiment, Mr. Toogood cut a rectangular sheet of pewter measuring 5⅜ in. long by 3⅝ in. wide (that is, approximately half the height of the crown which he was trying to duplicate) and 0.042 in. thick (substantially greater than the sheet in the crown but capable of making the results of the experiment visible to the naked eye) (Fig. 1). The choice of pewter and the size of sheet for the experiment were made for ease and speed of working. Mr. Toogood cut an arc out of each end, thus reducing the length of the centre line by 1¼ in. (Pl. 59). He then proceeded to stretch the centre line by hammering from the centre outward, in lines parallel to the centre line, to about ½ in. from the upper and lower edges, until the centre line was once more almost the same length as the upper and lower edges (Pl. 60). The metal was annealed twice during this operation and there was no problem in keeping the metal flat. The resulting sheet was then trimmed to form a rectangle, the thickness of which varied from 0.020 in. at the centre to 0.043 in. at the edges. This rectangle was bent around a horizontal stake to form a half-cylinder (Pl. 61). The upper and lower edges were stretched by hammering to form a waisted half-cylinder whose thickness measurements, at the waist, were 0.020 in. and, at the upper and lower edges, 0.042 in. (Pl. 62). It is interesting that the thickness at the edges is exactly the same as the original pewter sheet.

The operation took about 10 working hours. Extrapolating from this, Mr.

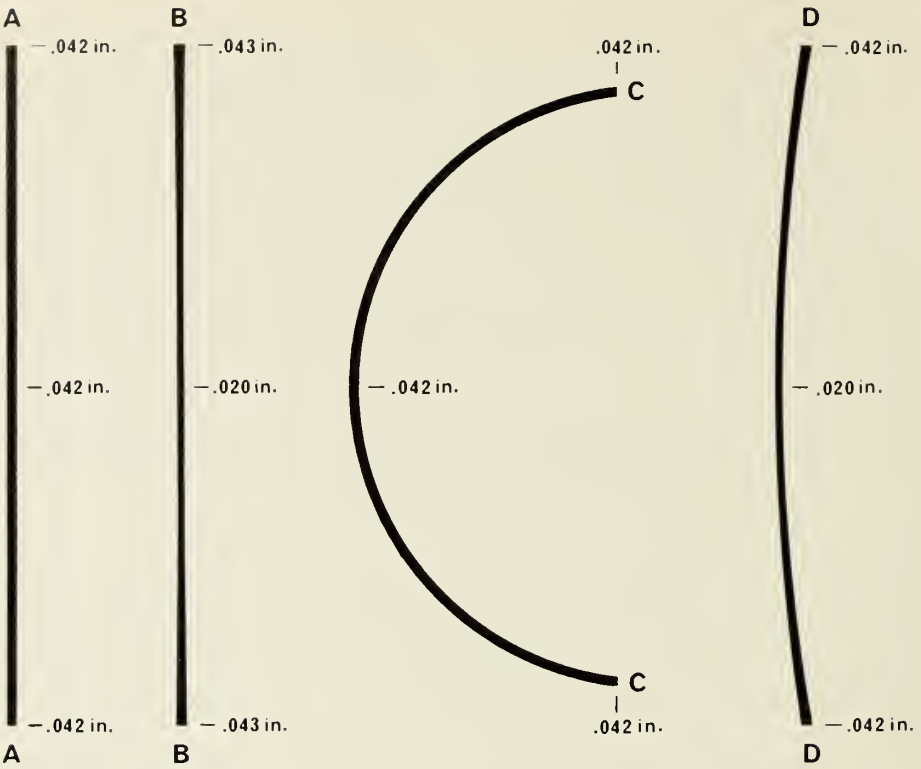


Fig. 1 Sketches to illustrate the stages of hammering and shaping to produce a half-facsimile of crown (*Cat.* 159, Reg. 3061) (cf. Pl. 59, 60, 61, and 62).

Toogood estimated that it would take about two weeks to make the waisted crown in the Museo Oro del Peru collection. It seems, to us, a laborious and unnecessarily complicated way of forming a waisted crown, and the reasons for adopting it are not immediately evident.

Mechanical Joining

As the craft of the ancient Peruvian metalworker was essentially restricted to working with sheet, it is not surprising that he developed a variety of joining techniques which were particularly appropriate for sheet. The waisted crown to which we have just referred (Pl. 55, 56, and 57, *Cat.* 159, Reg. 3061) is, almost literally, sewn together by passing a thin strip of metal through a series of slots cut in the overlapping edges of the sheet. Such lacing — which seems to be a modification of a practice developed for textile or leather working — is not uncommon, but the more usual method was to use shorter strips of metal which were passed through a pair of prepared holes and then bent down flat (with ends turned inward) — a procedure that approximates the use of the modern staple (see, for example, Pl. 8, 18, 19, 20, 75, and 77). Crimping, that is, the simple bending of the edge of one sheet tightly over

the edge of an adjacent sheet, is best exemplified in the joint at the widest circumference of the double-spouted, bridge-handled jar discussed above under Raising (p. 16). It is probable, as we have seen, that crimping would require annealing if the result were to be neat and tight without a rough "pleating" effect.

Crimping, perhaps, led to the use of tabs, that is, small, rectangular plaques cut out along the edge of the sheet to be inserted into slots in another sheet, either as a means of positioning for subsequent soldering, or as a mechanical joint. The use of tabs is illustrated in the jaguars (Pl. 63, *Cat.* 19, Reg. 2514, and references to Ms. Lechtman's studies in note 2), but also in the golden "gloves" (Pl. 64, *Cat.* 185, 186; Reg. 1902, 1903), at the point where the wrist joins the hand proper, apparently at the attachments of the fingers to the hand, and certainly at the end of the arm where, presumably, the "gloves" were joined to some other part of the ritual costume now missing. Even the fingernails were attached in this way. The same technique appears to have been used on the conch shell (Pl. 65, *Cat.* 149, Reg. 2904), and some beads (for example, Pl. 40, *Cat.* 293, Reg. 2049).

Before leaving the subject of mechanical joining by lacing, stapling, and the like, it is probably valuable to note the use of wire in a variety of ways. Pendant discs, lunates, triangles, and other such shapes on ear and nose ornaments, and masks are secured by wire loops, which allow the decorative shapes to move and reflect the light. Such wire was not drawn wire, but, in fact, very thin metal strips, square or rectangular in section, which were cut to the length desired and simply bent into a loop without any attempt being made to fasten the ends together. Such wire, of course, could be used as filigree but there are few examples of such a technique during Mochica and Chimu times — although it is common enough in the north in the Vicus and Frias cemeteries (see below). Where the wire is not rectangular in section, but round, it may simply have been produced by hammering the rectangular wire or, for greater thicknesses, by rolling a thin sheet of metal and hammering it into wire, as in the production of needles discussed above.

The thin cut gold foil applied on textiles was held in place by thread (Pl. 24, 25, and 26) although, in most cases, the threads we see today are modern replacements. Metal sheathing over wood was secured as we would expect, with tacks or nails, usually of copper; for example, the digging-stick (Pl. 66, *Cat.* 226, Reg. 1896; see, particularly, the colour photograph in the *Catalogue*, where the oxidized heads of the copper tacks show up clearly).

To conclude our treatment of mechanical methods of joining sheet metal to form more complex wholes we must note the small Inca figure of a llama (Pl. 67 and 68, *Cat.* 269, Reg. 3224). This tiny figure (only 2.5 cm high) which at first appeared, because of its very smooth surface, to be a casting, was revealed by the radiograph to be something completely different. It has been cleverly put together from at least six separate pieces of sheet shaped to form the head and ears, the neck, the forelegs, the body, the tail and hind quarters, and the back legs and penis. There is no evidence for solder, no sign of welding, no indication of any tabs or other aids to joining. On the

contrary, the several pieces appear to have been simply forced together, the obvious overlaps of material providing some rigidity. Unfortunately, our radiograph was taken just before the little masterpiece was packed and we had no opportunity to study it more closely — particularly under the microscope — to discover how the joins had been so cleverly hidden. We can only suggest that careful burnishing distributed the surface gold layer over the joins and concealed them.

Welding

The participants in the symposium gave much thought to the whole question of whether or not the ancient Peruvian craftsmen knew and used the relatively sophisticated technique of welding. Professor Lechtman, in her treatment of the jaguars, described a technique, to which she applied the term "sweat-welding", which is an approximation to true welding in that it definitely attempts fusion of contiguous metals. In the case of the jaguars this fusion was accomplished by placing between the edges of the sheets to be welded together an additional C-shaped strip of metal which could be brought to a temperature high enough to make it adhere — although most irregularly and unpredictably — to the two edges.[21] The fusion in this instance was accomplished not between the two contiguous edges of metal sheet directly but via an intermediate strip which, perhaps because of its thinness, could be raised to the temperatures required more easily than could the two pieces of metal sheet. It is assumed that the jaguar in the Mujica Gallo collection (Pl. 63, *Cat.* 19, Reg. 2514), which in every other respect (Pl. 69 and 70) appears to be identical with the other jaguars described by Ms. Lechtman, also exemplifies this technique, but no other examples were found in this collection during our studies.

There are, however, examples of another welding technique which does not require an intermediate metal strip but fuses contiguous edges of sheet metal with some degree of success. Our evidence for such a technique is most clear in three of the Vicus nose ornaments. In one of these (Pl. 71, Appendix B1, *Cat.* 34, Reg. 3327), one can see the sharp line of division between the portions with gold and silver surfaces. In the radiograph (Pl. 72) one can detect no transition zone of slightly different opacity to suggest the use of solder; there is no evidence for change of substance or structure, nor is there any indication of an overlap of the two sheets. There are, however, two thin black lines at the zone of juncture which suggest that the join is not complete; whether these are the result of incomplete fusion during the "welding" process, or represent cracks that occurred later at the line of joint, or — as Dr. Franklin suggests — an indication of the use of some organic adhesive (which would afford less obstruction to the X-ray), it is impossible to say at present.

No thickness measurements were taken on this object; we have, therefore, no evidence for a greater thickness at the line of junction which would support an hypothesis of abutting of the sheets, followed by rudimentary fusion (caused by application of heat) and subsequent hammering to strengthen the joint.

Another nose ornament (Pl. 73, Appendix B3, *Cat.* 45, Reg. 3362) was selected in Lima for the simple reason that already, at that early stage, we were curious about the method of joining what appeared to be two different metals (gold and silver), particularly in the Vicus nose ornaments. While the portion of the collection already travelling in Europe had many examples of such nose ornaments, they were rather fine, even outstanding, pieces and we required an example which was absolutely plain and could, we hoped, be submitted to tests which were not possible for those other handsomer and better-preserved pieces. Such tests, we hoped, might even illustrate our now abandoned hypothesis of parcel depletion gilding.[22] As matters turned out, we were not able to take samples at the line of juncture of the sheets of gold- and silver-surfaced metal, but the radiograph and thickness measurements do contribute something further to our knowledge. As with the preceding nose ornament, the line of juncture is quite sharp. Unlike *Catalogue* 34, however, there is no hair-line crack to indicate a poor joint, or a later cracking under strain, even where the radiograph (Pl. 74) demonstrates how thin the metal was in the lower part; the fusion has been quite successful.

The measurements of thickness are, however, interesting (Appendix B3, Fig. 5). If we leave out of the calculation those measurements (no. 14 and 15) which lie on the line of junction, we have an average thickness for the gold sheet of 0.026 in., and of the silver sheet, 0.030 in., although in both cases we can see that the thickness diminishes from the line of joint to the edges on either side and from the top to the bottom. The difference in average thickness may well be due to the loss of silver on the surface of the gold sheet in the final stages of the depletion gilding process. The thinning of both sheets towards the edges is best explained as a result of hammering after the two pieces were joined together. This may be supported by the fact that the greatest thickness of metal on the ornament (no. 14 — 0.046 in.) occurs on the centre line but this thickness also diminishes rapidly towards the bottom (no. 15 — 0.030 in.). There is, of course, no "seam" for there is no evidence whatsoever of overlapping. Mr. Toogood, however, did observe that in some cases at least where the gold- and silver-surfaced sheets were joined in these nose ornaments, there was evidence of bevelling of the edges which were to be joined; the very slight overlapping of the bevelled edges would not, of course, show up in the photograph or radiograph for the process is more akin to abutting than to overlapping. The evidence from this nose ornament, therefore, strengthens the case for assuming a knowledge of welding in early Peru; the evidence of thinning outward and downward from a central spine, where the two sheets have been abutted, suggests that hammering took place after the joining of the two sheets but not necessarily that it contributed to the strengthening of the joint.

The very ornate nose ornament (Appendix B2, *Cat.* 42, Reg. 3361) however, provides further evidence which suggests that hammering was not an adjunct to the fusing process. A comparison of the photograph and the radiograph (Pl. 75 and 76) shows that this complex and decorative piece is formed of seven separate pieces of sheet (exclusive of course, of the tiny gold discs attached by wire below the mask). The portion to the left consists

of three pieces: the central gold element (half the mask and one squirrel or feline), and one silver and one gold rectangle. The right-hand portion consists of four pieces: the central silver element (half the mask and one squirrel or feline), and two silver and one gold rectangle. The line between the innermost silver rectangle and the central silver portion is invisible in the photograph but quite clear in the radiograph. The joint is absolutely clean: there is no evidence of solder, no evidence of a crack; the fusion seems to be perfect.

If further evidence of a joint on this line is needed, we can compare the thicknesses of the metal as measured here (rows I and J on Fig. 4 of Appendix B2) and at the other points of junction (B/C, E/F, and G/H), where we have parallel phenomena. The quality of fusion, however, varies considerably. The joint between the gold central portion and the first silver rectangle is, again, perfect; close examination shows that the crack, which has occurred at this point and been repaired and strengthened (probably in modern times) by a plate secured to the reverse, does not coincide with the line of junction but is approximately 1.0 mm from it.

A similar situation holds along the central line of junction which runs through the human mask. Here, both photograph and radiograph show that the line of fusion between gold- and silver-surfaced sheets is almost vertical while the fracture, again strengthened by a rectangular plate affixed in modern times (see the radiograph, just above the human mask), shows up as a rather crooked line to the right of the joint. Visual examination of the reverse of this crack revealed the presence of some non-metallic adhesive (resin?) (Pl. 77 and 78) which appears to be covered in part with corrosion products; this could, then, be evidence for an ancient repair. We interpret this evidence as follows: the two sheets of metal were welded together by heat; the mask was then embossed, crossing the line of the joint between the two sheets; the deep embossing created great strain on the metal which finally fractured, but not at the line of the joint, which is an indication of the strength of that joint; the crack was repaired, in antiquity, with some non-metallic substance; finally, in modern times, a small rectangular plate was affixed to support (and perhaps renew) the ancient repair.

Apart from these very successful joints, there are three others (two on the right wing and one on the left wing) which were not so successful. The radiograph, particularly, shows some slight evidence of incomplete fusion although, in the second joint from the extremity of the right wing, the greater area of opacity may be a result of a crack on the line of juncture caused by some accident — perhaps even in modern times.

Up to this point we have adduced evidence for fusion at the lines of juncture between the seven constituent pieces. Is there evidence bearing on the question of whether or not hammering was an adjunct to the heating process? The radiograph provides no evidence whatsoever of overlapping at the joints. In fact, if we compare the measurements of thickness of metal on either side of the joints in the right wing, we notice that they are always substantially different: that is, the average thickness at J is 0.023 in. while at I it is only 0.014 in., at H it is 0.013 in, and G 0.0093 in.; similarly at F and E. There is no thickening at the line of juncture. If, in fact, we compare the

thicknesses at I and H, at G and F, and at E and D, we note that in each case these are closer than the thicknesses across the joints and that the metal sheets grow progressively thinner from J to I/H, to G/F, and E/D. The craftsman has used four gauges of metal in his construction of the nose ornament: the thickest in the central portion (that part with the mask which would actually be fastened to the septum of the wearer's nose), and the thinnest at the outer extremities. The reason for this is probably a practical one: to minimize the weight of the ornament as a whole while making the central portion capable of carrying the weight of the projecting wings. In assembling his components the craftsman has not attempted to graduate the thickness through the transition from one gauge to another — a graduation which could probably only be accomplished by hammering. The absolute lack of evidence for hammering to achieve such graduation is, at the same time, evidence that hammering was not a part of the welding process. We are left with the conclusion that in the case of the Vicus nose ornaments, at least, we have clear evidence of the knowledge of a technique of welding.

Any explanation for the use of such a relatively sophisticated technology in early Peru must be related, in some way, to that other technique for achieving gold and silver surfaces on an alloy of gold, silver, and copper, or of silver and copper which has been investigated by Professor Lechtman and called depletion gilding. We are not, therefore, seeking a method of welding pure gold and silver sheets together but rather of fusing sheets of very similar alloy, differing only in the fact that chemical action has been used to produce a gold surface on one sheet and silver on the other. This alloy would melt at a lower temperature than any of the constituent metals in a pure state.[23] The only further requirement would be the technical skill to apply heat locally, that is, at the point of juncture of the sheets. We have already, in our treatment of some of the more complex embossing procedures (as on the rattle), and in our study of the method used to produce the waisted crowns, assumed that the Peruvian metalworker had mastered such an art, that is, he could apply sufficient heat to melt the alloy exactly where it was needed without affecting other parts of the sheets being joined by such welding or fusion. If the use of an alloy was basic to the depletion gilding technique and also facilitated the welding process, and if the evidence is present that the Peruvian craftsman had the skill to apply the heat required for fusion where it was needed, it seems unlikely that the two processes were totally unrelated.

However, the three examples cited all come from the Vicus cemetery in the northern part of the country. Is there evidence for the use of welding in other parts of Peru and in later periods?

Perhaps it is not surprising that the only example of such welding observed occurs where (as with the Vicus nose ornaments) there was a need to join sheets with gold and silver surfaces, that is on the *tumi* or ceremonial knife (Appendix B4, *Cat.* 227, Reg. 2708).[24] The photograph (Pl. 79: again, the colour photograph of the *Catalogue* is more explicit) shows that the shaft and blade are made up of four pieces of gold-surfaced and four pieces of silver-surfaced sheet. In the radiograph (Pl. 80), the edges of the several sheets, at the lines of junction, are clear and there is no evidence of overlap

or solder; more important, at almost every joint there is firm welding with little suggestion of incomplete fusion. Only in the upper part of the shaft do we find evidence that fusion was not perfect or that subsequent strains had caused cracks to appear between the segments. When one considers that the great mask with crown and pendants, which forms the finial of the *tumi*, is held in place by mechanical pressure (it is slipped over the shaft) we can understand that strains would be exerted on the upper part of the shaft and weaken the joints in that section. One should notice also that, although we did not take thickness measurements on the *tumi*, a comparison of photograph and radiograph suggests that hammering had taken place on the blade after the welding to thin it towards the edge all round (like the Vicus nose ornament, Pl. 73 and 74, *Cat.* 45, Reg. 3362).

This *tumi* is the only example of welding from the post-Vicus period noted in the material loaned by the Museo Oro del Peru for the Canadian exhibition. It is rash to generalize from this single piece to the hypothesis that welding was used by the ancient Peruvian metalworkers *only* for joining sheets with gold and silver surfaces and *never* used for other purposes, and that the technique was far commoner in the early period (Vicus) than in subsequent periods. It is a hypothesis, however, which may lead to further investigations and analysis of techniques when the opportunity is provided.

Soldering

Apart from the mechanical methods of joining sheet and the welding techniques we have just discussed, the one technique for which we have some evidence is soldering. The best example in the Canadian exhibition was the exquisite miniature jar (Pl. 81, *Cat.* 259, Reg. 4670) of the Inca period. The two radiographs (Pl. 82 and 83) provide additional evidence. The flat rim is beautifully hammered and has been soldered to the neck; the X-ray (Pl. 82) shows the line of greater opacity at the join and visual examination reveals a silvery solder with signs of tooling. The neck and shoulder form a second section; the body to just below the greatest circumference forms a third; there is a join at about 1.0 mm above the line of the bottom; and finally there is the base itself, which is slightly concave. The handles are soldered flush with the body (Pl. 83); there is no evidence from the inside of the vessel that they have been inset in any way. It was not possible to sample the solder to learn its composition; in fact, the soldering was so beautifully done it would have been exceedingly difficult to find any excess to submit to testing.

There appears to be a limited use of solder in the Chimu period for filigree work and for joining tiny hollow gold balls to form elements in the ornament of *tumis* (note Pl. 79 and 80) and ear ornaments (for example, Pl. 84, *Cat.* 224, 225; Reg. 1884, 1885). Professor Lechtman has noted its use, much earlier, on the jaguars from Pampa Grande,[25] but a widespread use of solder is commonest in the metal objects from the Vicus and Frias cemeteries. As with the Chimu *tumis* and ear ornaments, the solder appears to be used mainly to secure wire (either square or round in section) to objects worked in

sheet. We may note the legs and antennae on the spiders (Pl. 85, *Cat.* 59, Reg. 3889 — Vicus), the crest, mouth, and teeth of the zoomorphic piece (Pl. 86, *Cat.* 63, Reg. 2513 — Frias), the manner in which the monkeys are secured to the upper edges of the pectoral (Pl. 87, *Cat.* 82, Reg. 2716 — Frias), and the laughing human faces of the birds (Pl. 88, *Cat.* 87, 88; Reg. 2520, 2521 — Frias). These, and many other pieces, use wire in a wide variety of interesting ways and secure it with solder.

We have, then, the puzzling fact of expert use of solder in the Inca period and the Vicus/Frias period nearly 1,500 years earlier, and very little evidence of its use (except in a few Chimu examples) in the intervening period. The re-introduction — if that is the word — of an expert use of solder in Inca times is paralleled by the apparently sudden appearance at the same time of a full-blown casting technique (p. 9). As casting involves melting the alloy, we are tempted to add to the list of strange coincidences, the common use of fusion-welding in the Vicus period, the lack of evidence for its widespread use in the subsequent Mochica, Chimu, and Inca periods, but the appearance of casting in the Inca period.

Such strange gaps in, and coincidence of, the use of techniques in periods that are chronologically separated by a millennium and a half lead us to look outside of modern Peru for the origin of these important innovations. Fortunately, the collection from the Museo Oro del Peru exhibited in Canada does, we believe, contribute evidence of some importance on this matter.

We have already noted that solder was used in the Vicus and Frias objects to secure wire to sheet. It is this very use of wire ornament in a large variety of ways (see examples given above) which distinguishes the Vicus and Frias styles from the later Mochica and Chimu styles. There could be no confusing the style of the little man seated on the serpent's head (Pl. 89) with anything we know from Mochica and Chimu times. The small thimble-shaped objects with decorated tops (*Cat.* 48, 49, 50; Reg. 5275, 5276, 5282 — Vicus) are not — as identified in the *Catalogue* — "thimbles, bobbins, or finials"; they are not open, as would be required if they were intended to fit over the end of a finger or the tip of a rod, but have a bottom piece, apparently soldered on. It is possible that they are ear-spools or labrets, objects not commonly used in Peru. The ear-cleaner (Pl. 90, *Cat.* 96, Reg. 2508 — Frias) appears to have a solid gold shank (like the two ear-cleaners from "Nazca" described above) and the motif of the bird-on-monkey which forms its finial is picked out in fine wire-work. This motif is not uncommon in Colombian metalwork of the Calima culture (that is, from the Pacific slope) but there the motif is in cast metal,[26] not, as here, sheet metal. One more example is the "tweezer" pendant (Pl. 91, *Cat.* 103, Reg. 2679 — Frias) which, again, resembles pieces from the Calima culture in Colombia.[27] Sylistic criteria, therefore, appear to complement and support the technological evidence and suggest that both soldering and casting (and we would include also welding) were practised in Colombia before they were introduced to Peru[28] and that the sites in the far north of Peru bear witness to a culture which was in many respects different from that of central and southern Peru (at least in the coastal regions). These stylistic and technological differences probably are closely related and have a direct bearing on our understanding of the triumphs and shortcomings of the Peruvian metalworker.

The Sources of the Techniques Used by the Peruvian Metalworker

We have noted, in our treatment of metalworking in ancient Peru, that the craft was essentially a sheet technique and that the chief form of ornament was embossing. The preparation of the sheet called for a high degree of skill — to achieve the close tolerances in thickness we have observed — and of metallurgical experience in the preparation of the sheet by the depletion gilding method. The fabrication of the sheet, in turn, required a relatively high degree of competence leading to the mass production of thousands of discs, lunates, plates, and many other forms of pendants, as well as the hollow gold balls of various sizes so beloved as beads or as trimming on other ornaments. Where the metalworker seems to have faltered, and often was downright clumsy, was in his cutting of the metal and in his assembling of parts into wholes, that is, where the techniques of shaping and joining larger pieces were involved. In both his achievements and in his failures we can see, perhaps, that the Peruvian worker in metal was not unaffected by the accomplishments and the shortcomings of craftsmen working with clay and fibres.

Our evidence for the early stages of metalworking in Peru (because of our selection of materials in the Canadian exhibition) derives from the cemeteries of Vicus and Frias in the far north of Peru. Because the material was looted, that is, removed for profit and not for archaeological evidence, there is nothing but stylistic evidence to indicate which objects belong chronologically together. Students have studied the pottery, particularly, and have noted differences of form and ornament, by which criteria they have assigned it to a variety of groups. On what appears to be a logical development of these stylistic peculiarities, the groups have been assigned a chronological order and context. Even if the scheme worked out for the pottery is correct, there is nothing to suggest how the metalwork from these cemeteries is related to the pottery groups and, to my knowledge, no attempt has been made to work out a stylistic grouping for the metal dependent entirely on criteria suited to it. What follows, therefore, must remain largely hypothetical — a quasi-logical explanation of the course of development of metallurgy and fabrication in early Peru based on criteria which appear to have some validity, even though they depend on the study of a very small portion of the whole bulk of the material coming from Vicus and Frias and there is a lack of examples from other important producing centres.

The production of gold and silver sheet by the depletion gilding technique is, we confess, without a close parallel in any other craft. The very long prehistory of trial and error which could finally develop a method by which a metal similar to pure gold or silver could be produced from an alloy of

gold, silver, and copper implies an incentive and a willingness to experiment which far exceeds the challenge facing the potter and weaver. The earliest examples of the technique available to us for study were the metal objects from the Vicus and Frias cemeteries. These already represent a sheet technique which was presumably developed in response to a desire for far greater quantities of sheet than could possibly be manufactured from pure gold available from alluvial deposits, or from gold and silver ores available from mines — at least with the facilities for extraction available to them. The first triumph of the Peruvian metalworker, then, was probably the production of sheet. Such an accomplishment goes back at least to the second millennium B.C.,[29] a time when Peruvian craftsmen were making great advances also in the fields of ceramics and textiles.

It is with the Vicus/Frias period in the north, however, and the Paracas period in the south — both dating roughly to the turn of the Christian era — that substantial advances were made in pottery and textile production; it can hardly be an accident that it is in this same period that we have good evidence for the production of gold and silver sheet by the depletion gilding technique. In other words, we can look upon the success of the metallurgist as a fitting parallel to the successes attained in other crafts at a time of florescence of Peruvian culture based on the assurance of an adequate food supply and the achievement of a social organization which could patronize the arts and crafts.

Whatever ceramic traditions may be recognized within the Vicus culture, it is agreed by all scholars that one characteristic was the modelling, by hand, of ornaments (*adornos*) to be attached to pottery; there is no evidence that moulds were used to produce such ornaments before they were affixed as appliqués to the clay wall of the vessel while it was wet or leather-hard.

The metalwork from the Vicus graves, however, appears to fall into at least two categories. The first category embraces those pieces which are most individual; they have not been stamped out against a mould (or over a mould) but have been embossed freely with some sort of punch against a firm but somewhat resilient backing (like pitch). In this category we would place several remarkable masks (Pl. 1, 92, and 93, *Cat.* 53, 54, 55, 58; Reg. 1226, 2213, 2216, 3861) as well as nose ornaments (such as Pl. 94, 95, and 96, *Cat.* 33, 35, 36; Reg. 3367, 3558, 3560). There can be no denying, especially in the masks, the power and feeling they project; the nose ornaments are less sophisticated, but have a charm of their own. Such pieces, we believe, can fully justify the claim that the metallurgist and fabricator were, so far, keeping pace with the artist working in clay.

Other metalwork from Vicus, however, while showing competence and even style, betrays the fact that moulds have been used in its ornamentation. Few of these are shown in our *Catalogue;* it seems now that in our selection of objects from the Museo Oro del Peru for the Canadian exhibition we subconsciously selected pieces which illustrate the first category and disregarded those which could illustrate this second group. The nose ornament (Pl. 97, *Cat.* 38, Reg. 3687), however, with its pair of addorsed bird figures, appears to have used the same mould for both (or, better, a mould and, perhaps, a clay model made from the mould to produce the

mirror image), the only difference being the result of a final surface chasing. The result is charming, but it points the way to a uniformity of production which could kill artistry. Such early mass production is perhaps most evident in the spider (Pl. 85, *Cat.* 59, Reg. 3889), of which only one of many was shown in the Canadian exhibition. The two-part bodies seem to have been embossed in identical moulds; slight differences are introduced, perhaps fortuitously, by the slightly different angles of the wires which make up the legs and antennae.

If this analysis is valid even in broad generalities we may be justified in seeking a parallel in pottery-making for the use of moulds, and consequent mass production, illustrated in the metalcraft of our second category. Dr. Day points out that in Mochica times (of which Vicus and Frias are now considered to be early and regional developments) large "face-neck" jars were produced which owe their name to the fact that the *adornos* (human and animal masks as well as other representations) were formed on the vertical necks of jars by holding a mould against the outside of the neck and forcing the soft clay from the inside of the neck into the mould. This paddle-anvil ceramic technique in association with a mould is closely akin to the embossing mould and punch technique we have recognized in our second metalworking category. We may then be justified in believing that the craftsman in metal and the craftsman in ceramics were following the same path of innovation in Peru in the early years of the first millennium A.D.

The subsequent development of the ceramic craft in Peru appears to have continued along the path already laid out — that is, a greater and greater dependence on the use of moulds — so that jars, bottles, and other forms came to be built up of several parts individually produced in moulds. The edges of the constituent parts, when leather-hard, were scored and moistened and then pressed together into a single whole before firing. That this increasing dependence on moulds by the potter was, at least in part, paralleled by a similar dependence on the part of the metalworker on moulds, punches, templates, and the like has been, we believe, illustrated above in our earlier description of the techniques used. The greatest use of such mass production was, apparently, in Chimu times, for both the potter and the metalworker.

In two important initial respects, however, the potter had an advantage over the fabricator of sheet metal. He had the marvellous substance, clay, which could be worked, shaped, and finished with comparative ease. He needed only bone, wood, or stone tools to cut and trim his products. Piece could be joined to piece merely by using a slightly thinned version of the clay mixture which had been used to build up individual parts of a vessel; handles, bases, spouts, and ornaments could be attached with relative ease. Joints could be strengthened, inside and/or outside, with added clay.

If, as we believe, the Vicus metalworker had mastered, as a direct concomitant of the depletion gilding technique, the art of welding, he was, in fact, using a joining method very close to the potter's technique. What is surprising is that such a direct method appears to have fallen into abeyance (with the exception of a few pieces such as the *tumi*, Pl. 79 and 80, *Cat.* 227,

Reg. 2708) and that the metal craftsman of the Mochica and Chimu cultures appears to have turned to the textile worker for techniques on how to join pieces of metal together.

It is an amazing fact that cotton was domesticated in Peru before any food plant and, with it, the Peruvian had at his disposal a magnificent resource which he could, and did, exploit to the fullest. The magnificent textiles and embroideries associated with Paracas and Nazca on the south coast and with the Mochica culture are well known throughout the world. Certain technical features of these textiles have a bearing on our study of Peruvian metalwork. Looms were narrow, and, when broad textiles were desired, the narrow products of the looms were simply sewn together side by side. It is interesting, also, that Peruvian taste did not, apparently, demand that the pattern of one strip correspond exactly with the pattern on an adjacent strip; in other words, we can see that there would be no surprise aroused when the craftsman who produced the waisted crown (*Cat.* 159, Reg. 3061) mutilated the embossed pattern after joining the two ends of the sheet.

We can carry our parallels further. The Peruvian weaver produced selvaged textiles which were not tailored in any way. The poncho is simply a rectangular sheet with a hole in the middle for the head to pass through; there is no fitting, no cutting, no hemming. There is no evidence that the ancient Peruvian developed any type of shears or scissors, and the knives of stone or metal at his disposal would not provide a clean cut. Whether they eschewed tailoring because they lacked satisfactory cutting implements or vice versa is not easily answered, but certainly the former possibility seems the more likely. If so, we can again see a factor of interest in our understanding of the metalworkers' difficulties; there was no instrument or tool available to the textile worker which could be borrowed or developed to meet his needs. His only tool was a chisel and the clumsy, uneven results of the use of a chisel can be seen in many places on the metalwork of Peru. There was, however, one technique intrinsic to the textile craft which could be adopted and adapted by the metalworker — the use of thread or cord to sew or tie things together. We have seen the evidence for lacing and stapling (which can be considered a development from lacing) metal sheets, and we can, probably, interpret the practice as the metal fabricator's attempt to find a method of joining which required (unlike welding or soldering) only a modicum of skill and no application of external heat.

Such a mechanical method, however, was less than satisfactory. The overlapping required must always leave an unfinished appearance, hardly acceptable aesthetically to those fabricators in metal who sought to achieve results not only functional but attractive. The fact remains that welding and soldering were used comparatively rarely in the Mochica and Chimu cultures and the dominant techniques for joining pieces of sheet metal were mechanical. It is possible that the general acceptance of what we would consider "unfinished" products — as exemplified in the textile industry — was sufficient to discourage any attempt on the part of the metal fabricators to go beyond such methods except in a few instances.

The triumph of soldering and casting in Inca times may parallel a political development already well recognized. The Inca Empire which, at the time of

the Spanish Conquest, covered all of what is now Peru, Ecuador, and parts of what are now Chile and Bolivia, had a mountain base (its capital was Cuzco) and was the culmination of a series of more localized cultures (Huari and Tiahuanaco) which also had their origin and strength in the piedmont or mountain areas. We may see in the triumph of the new metal technology evidence for a tradition of metalcraft which had prevailed for centuries in the cordilleras of Peru, Ecuador, Colombia, Chile, and Bolivia. It had exerted an influence on the early metalwork attributed to the Chavin and the "Chavinesque" cultures of the Peruvian coast and, later, in the border territories represented by the cemeteries of Vicus and Frias. During the period when the coastal powers, of Nazca, Mochica, and Chimu were dominant, such stimulus seems to have ceased. It is these coastal cultures, however, which have become normative for our presentation of Peruvian prehistory and it is their pottery, their textiles, their architecture, their metalwork which have become the hallmark, as it were, of Peruvian culture generally.

We have of necessity, because of the dominance of the metal objects of Mochica and Chimu origin (and to a lesser extent of Nazca origin) in the Canadian exhibition, continued to treat these cultures as normative, but we recognize that the complete lack of "Chavinesque" material in the loan collection has warped our view; only the strong representation of the Vicus and the Frias materials permits us to see that the coastal states do not represent the whole of Peruvian history and culture and that, particularly in the production of metal and the working of metal, these do not give us the complete picture. Part of the difficulty, we confess, lies in the present political divisions of northwest South America which do not represent ancient cultural provinces but which lead to a fragmented view of the whole cultural development of this part of South America. We should probably consider the metallurgical tradition as it is exemplified in Peru, Ecuador, Colombia, Bolivia, and Chile as one tradition, while recognizing that differences in style as well as differences in technique were originally local and dependent for their dissemination on many geographic, economic, and political factors which are, at present, not easy to recognize or evaluate.

In conclusion, we can state that the achievements of the metalworkers of Peru, as represented in the large number of examples of their work generously loaned by the Museo Oro del Peru for the exhibitions in Toronto, Winnipeg, and Montreal, are noteworthy and, in many cases, magnificent. Where we have discovered what we believe to be deficiencies, flaws, or failures, we are prepared to recognize the limited nature of the evidence — specifically that it represents chiefly the products of what we have called above the normative coastal valley cultures of Peru. Any successful attempt to illustrate the evolution of metalworking in Pre-Columbian America and to recognize its achievements must combine the finest products of that craft now housed in collections not only in Lima, Peru but also in Bogotá, Colombia, and Quito, Ecuador. Any narrower view will be partial and parochial. It may support local loyalties and nationalisms but it can never reveal the full sweep of the accomplishments, both technical and aesthetic, of the ancient Andean workers in metal.

Appendices

Appendix A1

Disc (Pl. 7, *Cat.* 5, Reg. 4011). Dia. 36.6 cm. Three suspension holes. Note: Pl. 6 is *Cat.* 6, Reg. 4012. Measurements of thickness taken from third hold clockwise to slight crack in rim (an arc of about 24 cm).

Disc *Cat.* 5, Reg. 4011

At 2 cm from rim	At 0.5 cm from rim
0.060 in.	0.107 in.
0.066 in.	0.1035 in.
0.064 in.	0.1035 in.
0.060 in.	0.101 in.
0.065 in.	0.1123 in.
0.059 in.	0.117 in.
0.070 in.	0.1172 in.
0.0675 in.	0.109 in.
0.073 in.	0.105 in.
Mean: 0.065 in. (1.65 mm)	0.108 in. (2.75 mm)
Minimum: 0.059 in. (1.50 mm)	0.101 in. (2.54 mm)
Maximum: 0.073 in. (1.85 mm)	0.1172 in. (2.98 mm)
Stand. Dev.: 0.0048 in. (0.12 mm)	0.006 in. (0.15 mm)

Appendix A2

Diadem (Pl. 8, *Cat.* 73, Reg. 2900). The diadem consists of two parts — a broad gold band to which small birds are attached and an embossed plume which may not originally have been associated with the band. The measurements on the band (Fig. 2) were made at 1 cm intervals on the upper edge and the lower edge in the arc from A to B, in each instance at 1 cm in from the edge. The section B to C was not measured because the reverse of the band had been covered with adhesive tape to strengthen the sheet and would have falsified the measurements. An equivalent area, arc C to D, was measured separately to discover whether there was an intentional thickening in this area to support the plume (there was, in fact, a slight thinning). The plume was measured separately at the points noted on sketch (Fig. 3).

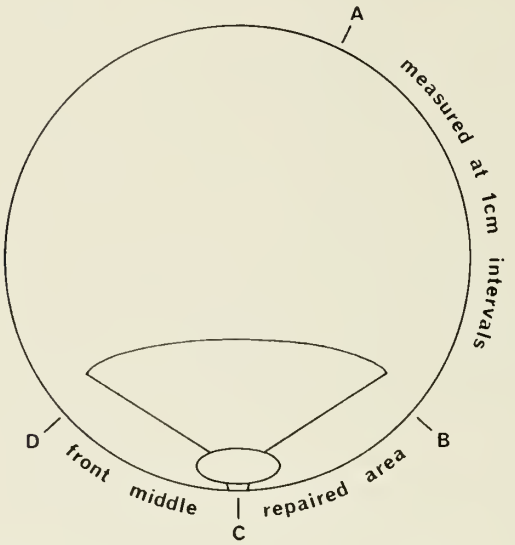


Fig. 2 Head-band of diadem (*Cat.* 73, Reg. 2900) (not to scale).

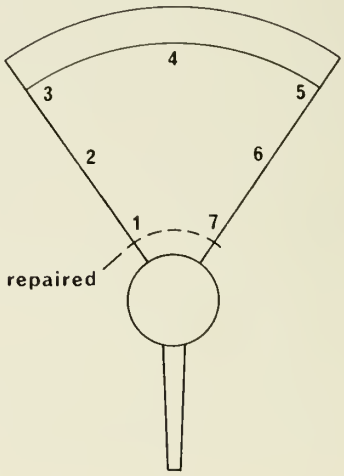


Fig. 3 Plume of diadem (not to scale).

Diadem Pl. 8, *Cat.* 73, Reg. 2900

Measurements in arc A to B		*Measurements in arc C to D*		*Measurements in plume*
Upper edge	Lower edge	Upper edge	Lower edge	
0.005 in.	0.0045 in.	0.0048 in.	0.0053 in.	1. 0.0065 in.
0.0048 in.	0.0042 in.	0.005 in.	0.0054 in.	2. 0.0048 in.
0.005 in.	0.0053 in.	0.0054 in.	0.0055 in.	3. 0.0057 in.
0.005 in.	0.0061 in.	0.0045 in.	0.0057 in.	4. 0.0067 in.
0.0043 in.	0.0047 in.	0.0039 in.	0.0052 in.	5. 0.0048 in.
0.0046 in.	0.005 in.	0.004 in.	0.0045 in.	6. 0.0055 in.
0.0046 in.	0.0048 in.	0.0042 in.	0.0052 in.	7. 0.0075 in.
0.005 in.	0.0042 in.	0.0043 in.	0.0043 in.	
0.0054 in.	0.0045 in.			
0.0055 in.	0.005 in.			
0.0053 in.	0.0048 in.			
0.0048 in.				
0.0048 in.				
0.0055 in.				
0.0045 in.				

Appendix A3

Helmet (Pl. 9 and 10, *Cat.* 133, Reg. 4264). Measurements of sheet gold rectangles covering, and secured to, the canes which were bent and tied together with cord to form the hemispherical helmet.

Helmet Pl. 9 and 10, *Cat.* 133, Reg. 4264

Length of rectangle	Thickness
13.0 mm	0.0043 in.
12.0 mm	0.0045 in.
13.0 mm	0.0040 in.
12.0 mm	0.0042 in.
12.5 mm	0.0036 in.
11.5 mm	
12.5 mm	
12.0 mm	
Mean: 12.3 mm	0.0041 in. (0.10 mm)
Minimum: 11.5 mm	0.0036 in. (0.09 mm)
Maximum: 13.0 mm	0.0045 in. (0.11 mm)
Stand. Dev.:	0.00034 in. (0.01 mm)

Appendix A4

Poncho (Pl. 11 and 12, *Cat.* 136, Reg. 1906). Measurements of seven of the gold plaques.

Poncho Pl. 11 and 12, *Cat.* 136, Reg. 1906

Measurements of plaques	Thickness
13.0 mm × 13.0 mm	0.0045 in.
13.0 mm × 13.5 mm	0.0036 in.
14.5 mm × 13.0 mm	0.0029 in.
13.0 mm × 13.0 mm	0.0032 in.
12.8 mm × 13.0 mm	0.0043 in.
13.0 mm × 14.2 mm	0.0042 in.
13.8 mm × 13.5 mm	0.0030 in.
Mean:	0.0037 in. (0.09 mm)
Minimum: 12.8 mm × 13.0 mm	0.0029 in. (0.07 mm)
Maximum: 14.5 mm × 13.0 mm	0.0045 in. (0.11 mm)
Stand. Dev.:	0.0007 in. (0.02 mm)

Appendix A5

Crown (Pl. 60, 61, and 62, *Cat.* 159, Reg. 3061). Measurements were taken along the top and bottom edges (avoiding the seam and far enough away from the edges to be clear of the effects of cutting and crimping) and at the waist.

Crown Pl. 60, 61, and 62, *Cat.* 159, Reg. 3061

	Measurements of thickness		
	Top edge	Bottom edge	Waist
	0.0140 in.	0.0110 in.	0.0058 in.
	0.0173 in.	0.0108 in.	0.0042 in.
	0.0145 in.	0.0112 in.	0.0043 in.
	0.0170 in.	0.0100 in.	0.0043 in.
	0.0159 in.	0.0128 in.	0.0040 in.
	0.0145 in.	0.0110 in.	0.0058 in.
	0.0140 in.	0.0112 in.	0.0046 in.
	0.0150 in.	0.0108 in.	0.0062 in.
Mean:	0.0153 in. (0.39 mm)	0.0111 in. (0.28 mm)	0.0049 in. (0.13 mm)
Minimum:	0.0140 in. (0.36 mm)	0.0100 in. (0.25 mm)	0.0040 in. (0.10 mm)
Maximum:	0.0173 in. (0.44 mm)	0.0128 in. (0.33 mm)	0.0062 in. (0.16 mm)

Note: (1) The top edge is thicker than the bottom; (2) thickness at the waist is at least half that at either top or bottom edge; (3) the variations in thickness are of the same order at top and bottom edges; (4) the variation in thickness at waist is at least twice that at either top or bottom edge.

Appendix B1

Nose ornament—Vicus (Pl. 71 and 72, *Cat.* 34, Reg. 3327). H. 7.7 cm, W. 9.4 cm. No thickness measurements were taken on this object.

Appendix B2

Nose ornament—Vicus (Pl. 75, 76, and 77, *Cat.* 42, Reg. 3361). H. 11 cm, W. 17 cm.

Nose ornament Pl. 75, 76, and 77, *Cat.* 42, Reg. 3361

Section A	Section B	Section C	Section D	Section E
0.0075 in.	0.0102 in.		0.0095 in.	0.0085 in.
0.0068 in.	0.0085 in.	No	0.0078 in.	0.0072 in.
0.0078 in.	0.0092 in.	measurements	0.0078 in.	0.0072 in.
0.0088 in.	0.0098 in.	taken	0.0081 in.	0.0072 in.
0.0086 in.	0.0095 in.		0.0083 in.	0.0075 in.
Mean: 0.0077 in.	0.0094 in.		0.0083 in.	0.0075 in.

Section F	Section G	Section H	Section I	Section J
0.0101 in.	0.0096 in.	0.0130 in.	0.0143 in.	0.0223 in.
0.0099 in.	0.0095 in.	0.0132 in.	0.0141 in.	0.0224 in.
0.0095 in.	0.0092 in.	0.0129 in.	0.0134 in.	0.0226 in.
0.0093 in.	0.0090 in.	0.0128 in.	0.0138 in.	0.0230 in.
0.0093 in.	0.0092 in.	0.0130 in.	0.0144 in.	0.0248 in.
Mean: 0.0096 in.	0.0093 in.	0.0130 in.	0.0140 in.	0.0230 in.

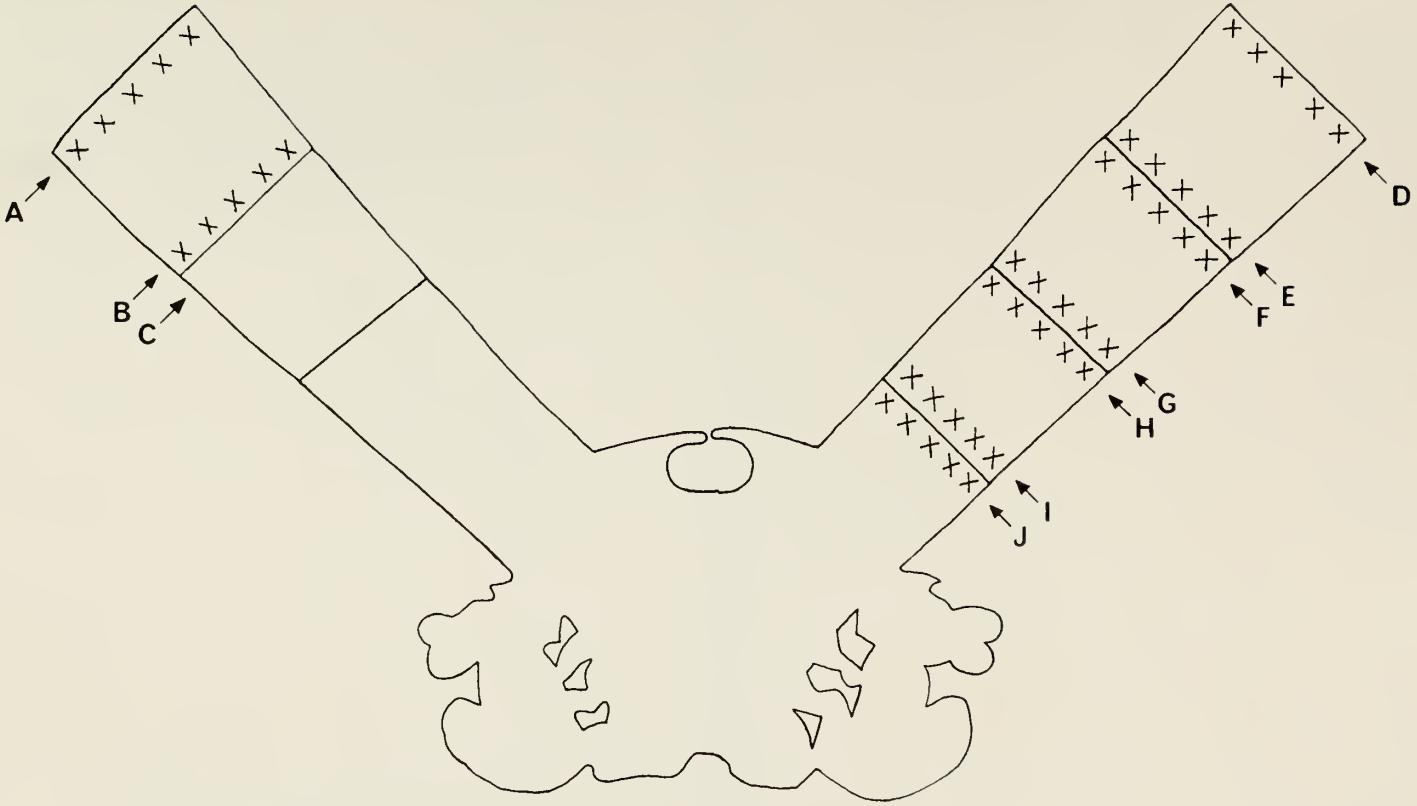


Fig. 4 Drawing of nose ornament (*Cat.* 42, Reg. 3361) to scale, indicating points at which measurements of thickness were made. Each row of five measurements was made starting at the outside edge and moving inward, as shown by arrows. Measurements at Section C were not attempted because of layers of adhesive on back of ornament which could not be removed.

Appendix B3

Nose ornament—Vicus (Pl. 73 and 74, *Cat.* 45, Reg. 3362). H. 5.7 cm, W. 7.8 cm.

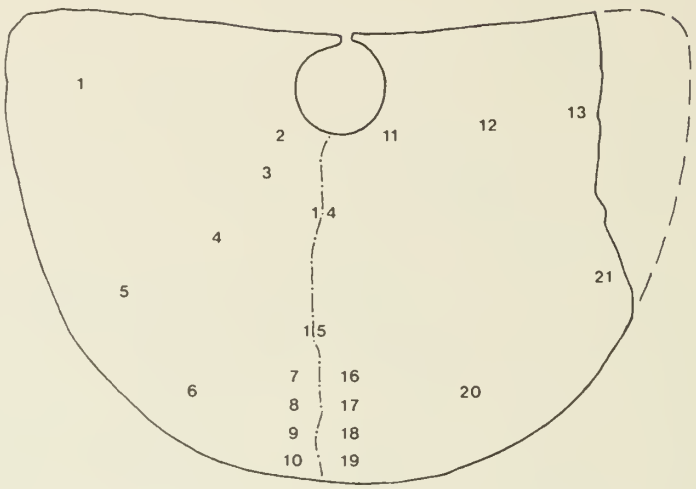


Fig. 5 Drawing of nose ornament (*Cat.* 45, Reg. 3362) to scale, indicating points at which measurements of thickness were made.

Nose ornament Pl. 73 and 74, *Cat.* 45, Reg. 3362

Gold side	Mid-line	Silver side
1. 0.017 in.	14. 0.046 in.	11. 0.039 in.
2. 0.0345 in.	15. 0.030 in.	12. 0.037 in.
3. 0.033 in.		13. 0.0325 in.
4. 0.029 in.		16. 0.0375 in.
5. 0.026 in.		17. 0.027 in.
6. 0.023 in.		18. 0.020 in.
7. 0.034 in.		19. 0.020 in.
8. 0.027 in.		20. 0.027 in.
9. 0.020 in.		21. 0.025 in.
10. 0.0175 in.		
Mean: 0.026 in.		0.030 in.

Appendix B4

Tumi (ceremonial knife) (Pl. 79 and 80, *Cat.* 227, Reg. 2708). Lambayeque style, Chimu. H. 27.7 cm, W. 10.3 cm. Blade and shaft consist of alternating sections of gold- and silver-surfaced alloy.

Notes

1. The exhibition was presented at the Royal Ontario Museum in Toronto, September 28 to November 21, 1976; at the Winnipeg Art Gallery, December 17, 1976 to February 20, 1977; and at the Montreal Museum of Fine Arts, March 18 to May 15, 1977.

2. See H. N. Lechtman, "Ancient methods of gilding silver: examples from the Old and the New Worlds", in R. H. Brill ed., *Science and Archaeology* (Cambridge, Mass.: Massachusetts Institute of Technology Press, 1971), pp. 2–30; "The gilding of metals in Precolumbian Peru", in W. J. Young ed., *The Application of Science in Examination of Works of Art* (Boston: Museum of Fine Art, 1973), pp. 38–52; H. N. Lechtman, L. A. Parson, and W. J. Young *Seven Matched Hollow Gold Jaguars from Peru's Early Horizon*, Studies in Pre-Columbian Art & Archaeology 16 (Washington, D.C.: Dumbarton Oaks, Trustees for Harvard University, 1975), 46 pp.; see also, for a broader picture of the techniques in the whole of ancient America, Warwick Bray, "Gold working in ancient America" and "The organization of the metal trade" in *El Dorado: The Gold of Ancient Colombia* (New York: Center for Inter-American Relations and American Federation of Arts, 1974), pp. 33 ff.

3. J. W. Grossman, "An ancient gold worker's tool kit: the earliest metal technology in Peru", *Archaeology* vol. 25, no. 4 (October 1972), pp. 270–275; H. N. Lechtman, "A metallurgical site survey in the Peruvian Andes", *Journal of Field Archaeology* vol. 3, no. 1 (1976), pp. 1 ff.

4. A. D. Tushingham, *Gold for the Gods* (Toronto: Royal Ontario Museum, 1976) (hereafter *Catalogue* — available in English or French).

5. M. Mujica Gallo, *Catalogue, Museum Gold of Peru* (Lima: Mujica Gallo Foundation, 1970). This catalogue is, unfortunately, out of print, but is, we understand, being revised and prepared for republication.

6. Swarthmore, Penn. U.S.A.: Joint Committee on Powder Diffraction Standards, 1976.

7. R. G. V. Hancock, "Low flux multielement neutron activation analysis in archaeometry", *Analytical Chemistry* 48 (1976), pp. 1443–45.

8. See references in note 2 and *Catalogue*, pp. 58–59.

9. The evidence that the technique was used for some 1,500 years before the Spanish Conquest allows us to show, on other than stylistic grounds, that two of the pieces shown in the Toronto exhibition (the "breastplates" *Cat.* 364, 365; Reg. 128, 133) are in fact forgeries. Sr. Mujica Gallo has informed us that he has always considered them fakes but his judgement has now received strong confirmation from X-ray diffraction studies which demonstrate conclusively that the surfaces of the metal sheet and attached plaques contain copper nitrate hydroxide — $Cu_2(OH)_3NO_3$ — with occasional admixture of cuprous oxide Cu_2O and silicon dioxide SiO_2.

10. See note 3. Note that we are here speaking of sheet fabrication, not the depletion gilding technique.

11. G. Petersen, "Mineria y metalurgia en el Antiquo Peru", *Arquelogicas* 12 (1970), fig. 2.5–9.

12. *Ibid.*, fig. 10.5.

13. *Ibid.*, fig. 12 (also reproduced in *Catalogue*, p. 56).

14. As suggested in *Catalogue*, p. 58.

15. See *Catalogue*, p. 52.

16. *Indigenous Art of the Americas.* Collection of Robert Woods Bliss (Washington, D.C.: National Gallery of Art, 1947), pp. 146-147.

17. The third example in the loan collection (*Cat.* 235, Reg. 1651) forms the head-piece to which are now attached five other large ornamental pieces; it is completely plain.

18. We have used the term "breastplate" in quotation marks to indicate our doubt that the elements of which it is now constituted originally went together in this way. However, we do not doubt that breastplates or ceremonial jackets of this form were used at the time. Good examples are illustrated on the ear ornaments (*Cat.* 179, 180; Reg. 1969, 1970).

19. It is true that there are pieces of chrysocolla and turquoise without holes now decorating some of the objects. Because there is no evidence that these were set into bezels contrived for the purpose, we can only assume that they were held in place with some adhesive, presumably organic. Such an adhesive would probably have perished over the centuries of burial, just as the original threading of beads has usually disappeared. The illicit excavators of Peru's ancient cemeteries would, therefore, find large quantities of semi-precious stones — some without holes, far more with holes — in their operations. We can understand their belief that objects which they found (crowns, ear ornaments, jewellery of various kinds) could be enhanced, both aesthetically and commercially, by applying some of these stones to the objects (again with glue) just as they would restring many of the beads. The result of this unknown factor — the extent to which the present state of the objects represents their original state — is that we can have no assurance that beads with holes which are now so liberally used as ornament on the larger objects were originally used in this way. This gap in our knowledge means that we cannot be certain that the intent of the ancient bead maker was to mass produce material which could be used as beads or inlay, but it is difficult to escape the conclusion that there was, in fact, mass production.

20. Warwick Bray, in "Ancient American metal-smiths", *Proceedings of the Royal Anthropological Institute of Great Britain and Ireland for 1971* (London: RAI, 1972), pp. 25–43, describes (p. 27) and illustrates (pl. 5) a wooden (?) slab with concave depressions into which sheet metal could be hammered. He also describes and illustrates (p. 27 and fig. 2) the production of more complex forms by hammering sheet over solid wooden or cast bronze forms in the Chimu and Chimu-Inca periods.

21. H. N. Lechtman, L. A. Parson, and W. J. Young *Seven Matched Hollow Gold Jaguars from Peru's Early Horizon,* Studies in Pre-Columbian Art & Archaeology 16 (Washington, D. C.: Dumbarton Oaks, Trustees for Harvard University, 1975), 46 pp.

22. See *Catalogue,* pp. 59-60.

23. *Metals Handbook,* 8th edition (Metals Park, Ohio: American Society of

Metals, 1976), vol. 8, p. 378. For the record it should be noted that welding or soldering of pure metals — gold to gold and gold to silver — is reported by S. K. Lothrop in two articles "Gold ornaments of Chavin style from Chongoyape, Peru", *American Antiquity* VI (1940-41), pp. 250-262 and "Gold artifacts of Chavin style", *American Antiquity* XVI (1950-51), pp. 226–240. Analyses of some of the objects are given in the second article in table 14, p. 238. Lothrop's final remarks (*ibid.* p. 239) are, however, pertinent here: "In conclusion we may state that Chavin gold was an early development, brilliant in style and in techniques of manufacture. It was, however, largely an isolated phenomenon which contributed comparatively little to subsequent cultures. Forms and processes apparently had to be created a second time." Was this early aborting of metallurgical evolution in Peru a result of the development of a cheaper (and easier) method of producing objects with gold and silver surfaces by the depletion gilding method from alloys of gold, silver, and copper or silver and copper which were also more easily soldered and welded?

24. The apparently similar *tumi* (*Cat.* 234, Reg. 3059) is, in fact, composite. It is possible that the finial and gold sections originally belonged to such a *tumi* but the grey sections and the whole support are of some plastic substance, not silvered metal; it can only be considered a modern reconstruction.

25. H. N. Lechtman, L. A. Parson, and W. J. Young *Seven Matched Hollow Gold Jaguars from Peru's Early Horizon*, Studies in Pre-Columbian Art & Archaeology 16 (Washington, D.C.: Dumbarton Oaks, Trustees for Harvard University, 1975), 46 pp.

26. *El Dorado: The Gold of Ancient Colombia* (New York: Center for Inter-American Relations and the American Federation of the Arts, 1974), no. 44.

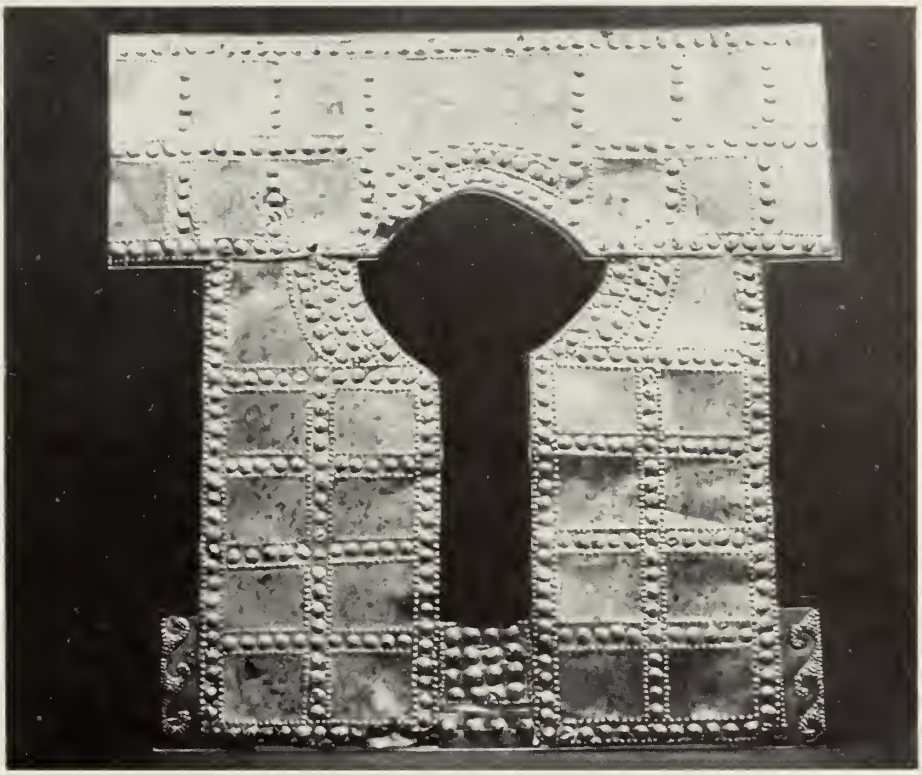
27. *Ibid.*, no. 41.

28. It must be remembered that the jaguars described by Prof. Lechtman, which reveal a knowledge of soldering and a peculiar form of sweat-welding, also came from the northern part of Peru — the Lambayeque valley.

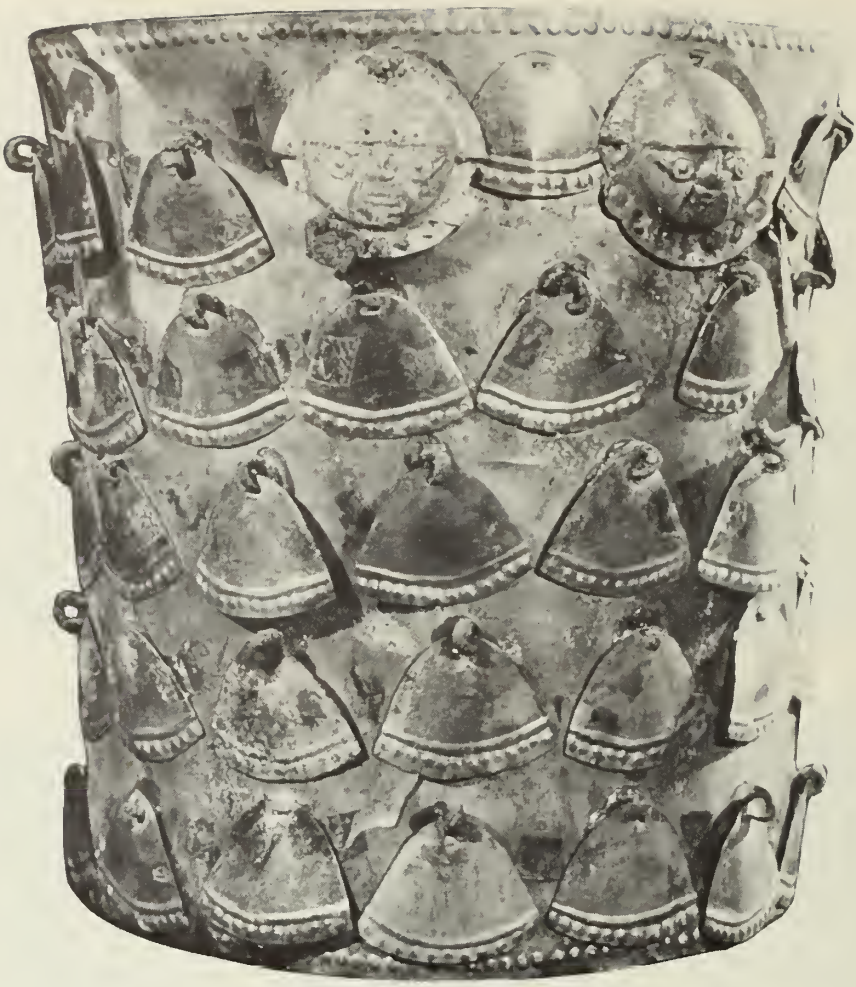
29. See Grossman, note 3. To my knowledge, no analysis has been made of the fragments of gold leaf which he found; we do not know whether they are pure gold or productions of the depletion gilding technique.

Plates

Pl. 1 Silver funerary mask (*Cat.* 53, Reg. 1226). Vicus culture. H. 18.0 cm; W. 38.5 cm.



Pl. 2 "Breastplate" reconstructed from embossed sheets (*Cat.* 150, Reg. 46). Chimu? H. 47.8 cm; W. 47.0 cm.



Pl. 3 Crown (*Cat.* 228, Reg. 2881). Chimu, Lambayeque style. H. 22.0 cm; Dia. 20.0 cm.

Pl. 4 "Breastplate" of Pl. 2. Photomicrograph of edge at magnification of 125×.

Pl. 5 "Breastplate" of Pl. 2. Photomicrograph of edge at magnification of 300×.

Pl. 6 Disc (*Cat*. 6, Reg. 4012). Line of arc on surface is caused by one disc resting against another.

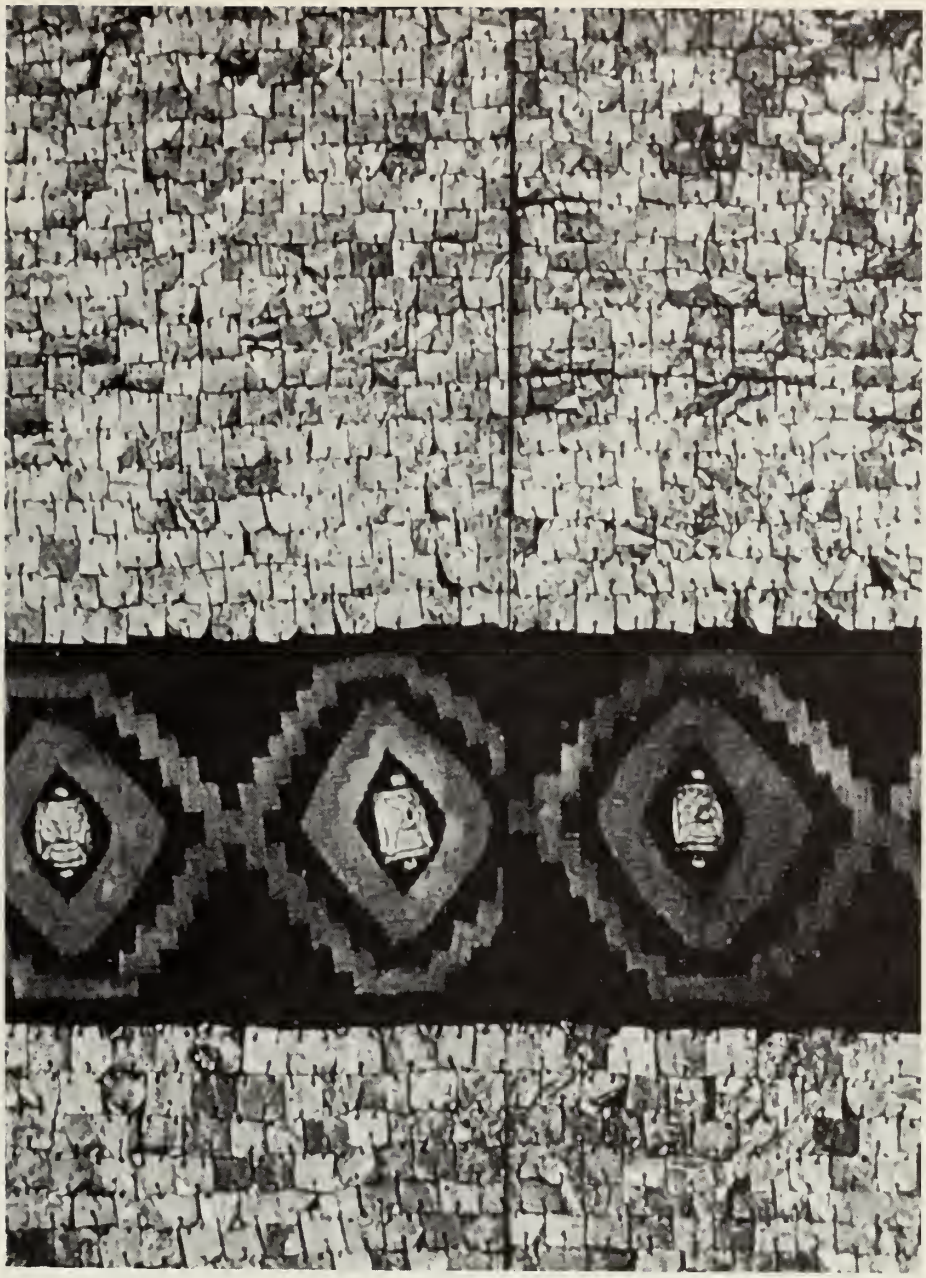
Pl. 7 Disc (*Cat*. 5, Reg. 4011). Radiograph showing three holes, slight crack at rim (lower right in photograph), and evidence of hammering.

Pl. 8 Diadem with plume (association of two may not be original) (*Cat.* 73, Reg. 2900). Mochica (Frias). H. (with plume) 18.0 cm; W. of band 5.0 cm.

Pl. 9 Bonnet or helmet (*Cat.* 133, Reg. 4264). Nazca. H. 19.0 cm; Dia. 28.0 cm.

Pl. 10 Bonnet of Pl. 9. Detail to show method of fastening of plaques.

Pl. 11 Poncho (*Cat*. 136, Reg. 1906). Chimu? L. 206.0 cm; W. 84.0 cm.



Pl. 12 Poncho of Pl. 11. Detail to show method of fastening of plaques to textile. Magnification ca 0.5×.

Pl. 13 Mace head (*Cat*. 271, Reg. 2054). Inca. Cast copper or bronze with gold surface. Detail.

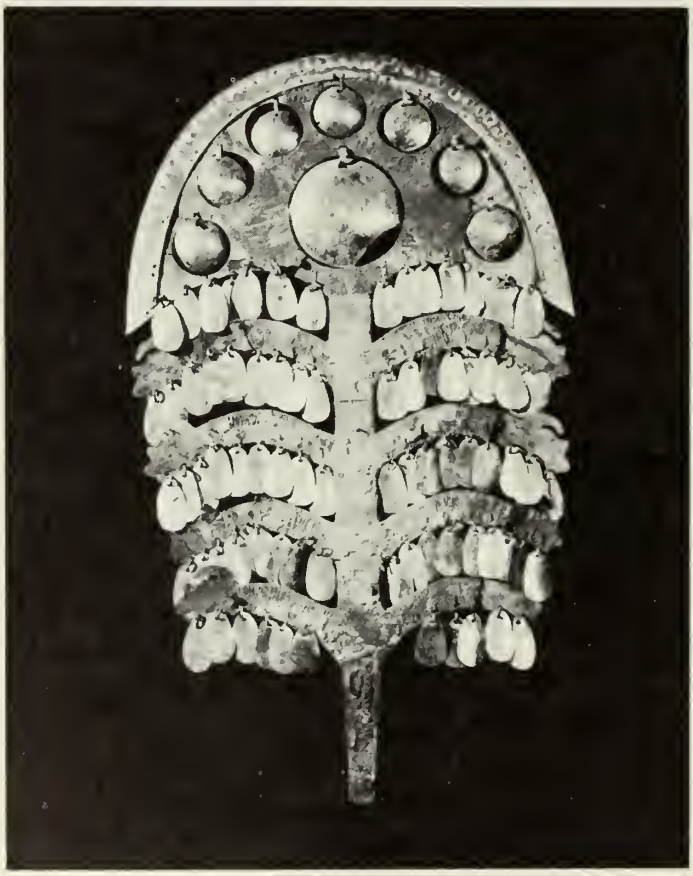
Pl. 14 Balance beam (*Cat*. 270, Reg. 3311). Inca. H. 4.7 cm; W. 6.8 cm.

Pl. 15 Lame male figure with a crutch (*Cat.* 264, Reg. 3218). Inca. H. 3.6 cm.

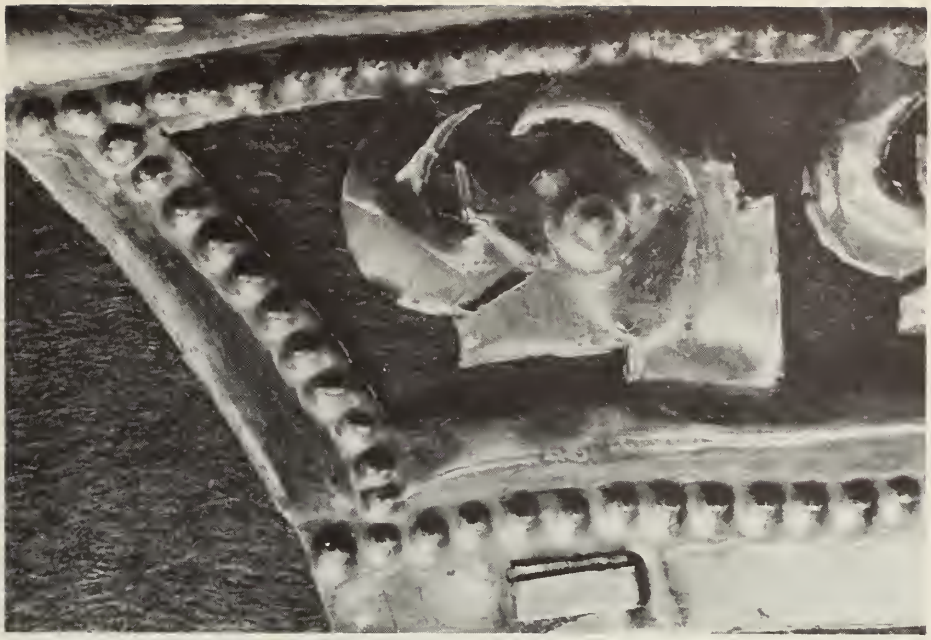
Pl. 17 Ear-cleaners (*Cat.* 125, 126; Reg. 2305, 4823). Inca L. 6.7 and 8.0 cm.

Pl. 16 Necklace (*Cat.* 349, Reg. 433). Restrung. Radiograph of pendants which include sheet gold cones and cast openwork silver bells with anthropomorphic features (latter measuring ca 2.3 cm long).

Pl. 18 Arc-shaped crest from object similar to Pl. 19 (*Cat.* 231, Reg. 2714). Chimu? Greatest W. 34.0 cm; breadth of band 5.3 cm.



Pl. 19 Standard or part of crown (*Cat.* 244, Reg. 2879). Chimu H. 32.3 cm.

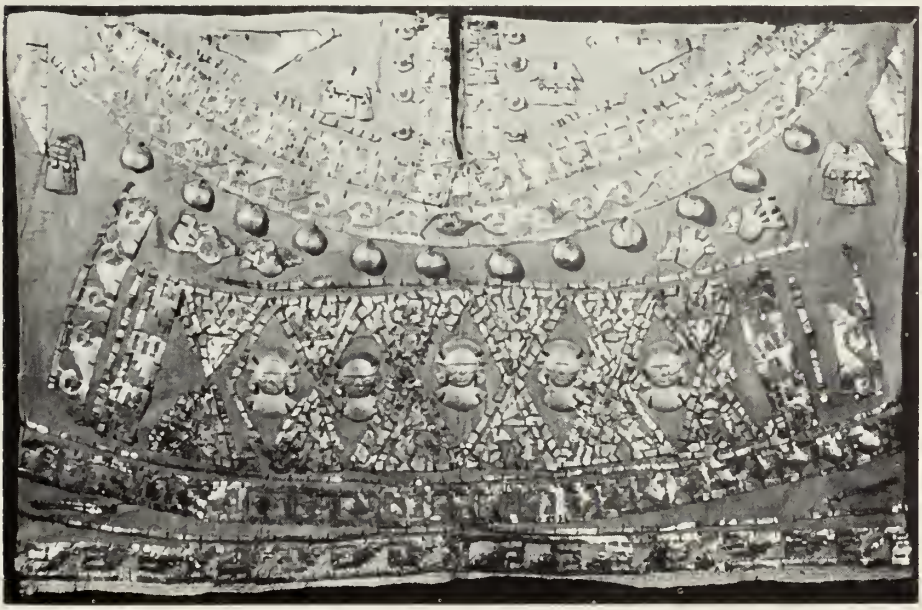


Pl. 20 Detail of object illustrated in Pl. 18.

Pl. 21 Radiograph of object illustrated in Pl. 18.

Pl. 22 Detail of reverse of "breastplate" illustrated in Pl. 2.

Pl. 23 Round sheet of silver, embossed, possibly the cover for a shield of leather, wood, or woven cane (*Cat.* 246, Reg. 4841). Chimu. Dia. 34.8 cm.



Pl. 24 Child's poncho (*Cat.* 238, Reg. 4114). Chimu. W. (at shoulder) 49.5 cm.

Pl. 25 Rectangular bag (*Cat.* 74, Reg. 4132). Mochica (Frias). H. (without strap) 24.0 cm; W. 34.0 cm.

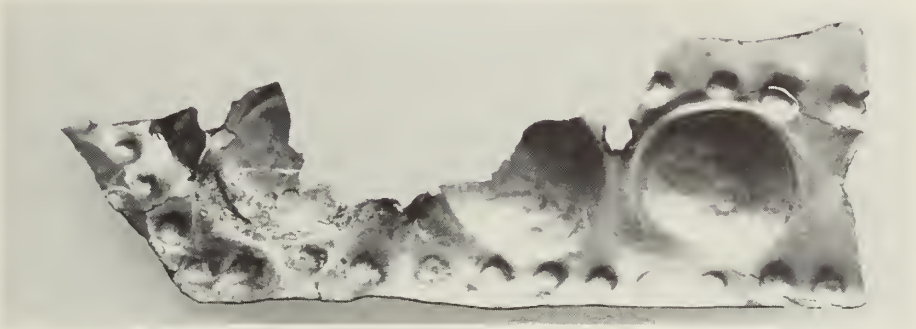
Pl. 26 Fragment of textile (*Cat.* 134, unregistered). Chimu? H. 46.0 cm; W. 66.0 cm.

Pl. 27 Gold vessel (*Cat.* 162, Reg. 4652). Chimu. L. 24.0 cm; H. 16.0 cm.

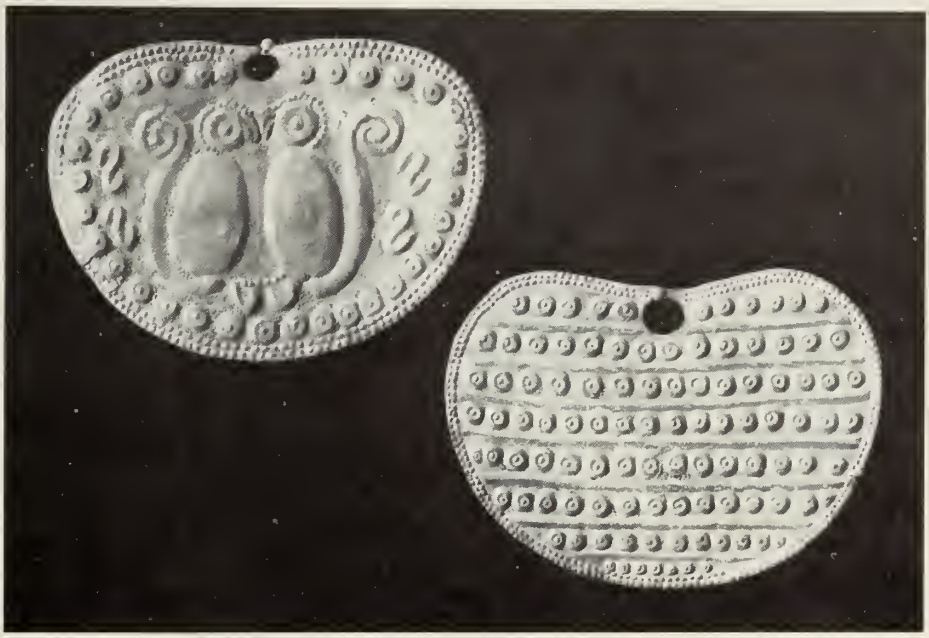
Pl. 28 Necklace with pendants inlaid with turquoise or chrysocolla beads (*Cat.* 304, Reg. 464). Restrung. Pendants are Chimu, Lambayeque style. L. 71.0 cm.

Pl. 29 Mask (*Cat.* 57, Reg. 3772). Vicus. H. 18.5 cm; W. 19.0 cm.

Pl. 30 Detail of "breastplate", Pl. 2. Exterior.



Pl. 31 Detail of "breastplate", Pl. 2. Interior.



Pl. 32 Nose ornaments. Vicus. (*Cat*. 27, Reg. 3564). H. 8.6 cm; W. 12.0 cm. (*Cat*. 28, Reg. 3565). H. 8.8 cm; W. 12.0 cm.

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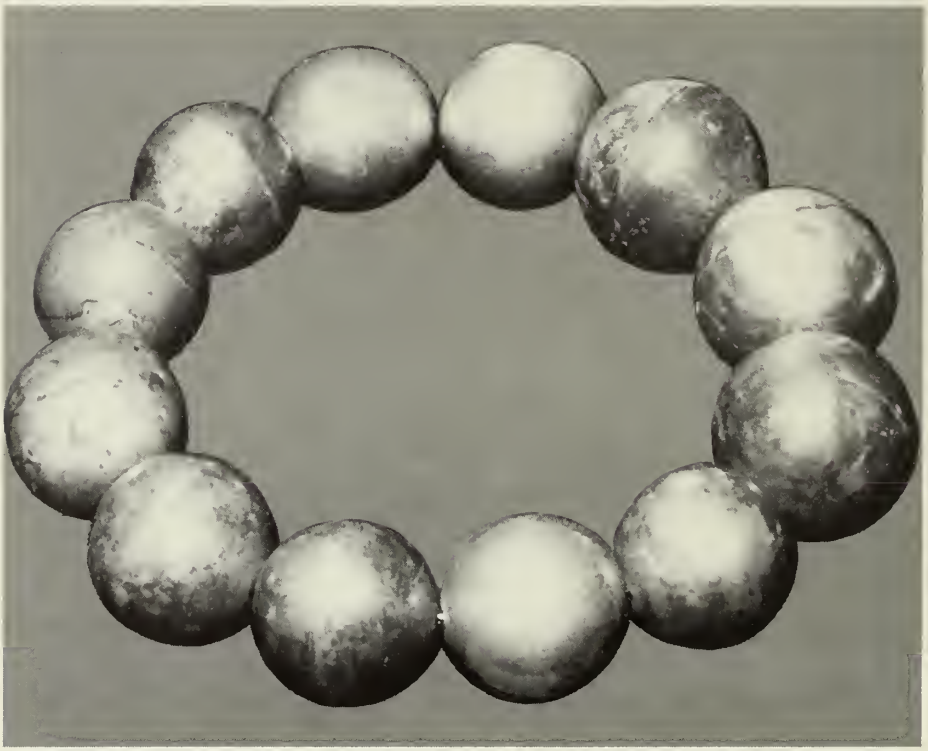
Pl. 33 "Wrist guard" (*Cat*. 131, Reg. 3238). Nazca. L. 19.9 cm.

Pl. 34 Rattle (*Cat*. 116, Reg. 265). Mochica? L. 32.6 cm; W. (across bottom) 23.8 cm.

Pl. 35 Rattle. Detail of top to show embossing, fold-over, and tube for hinge of suspension.

Pl. 36 Ear spools (*Cat*. 105, 106; Reg. 4922, 4923). Mochica. Dia. 7.5 cm.



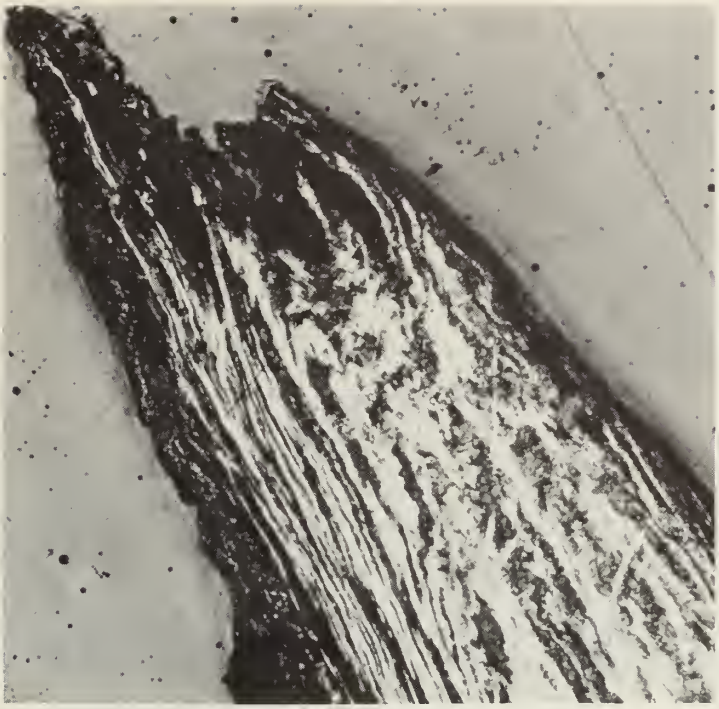
Pl. 37 Necklace of large, hollow gold balls (*Cat*. 323, Reg. 1628). Restrung. Dias. 5.2 to 6.4 cm.

Pl. 38 Radiograph of necklace of Pl. 37.

Pl. 39 Necklace of hollow beads in form of fish vertebrae (*Cat.* 293, Reg. 2049). Restrung.

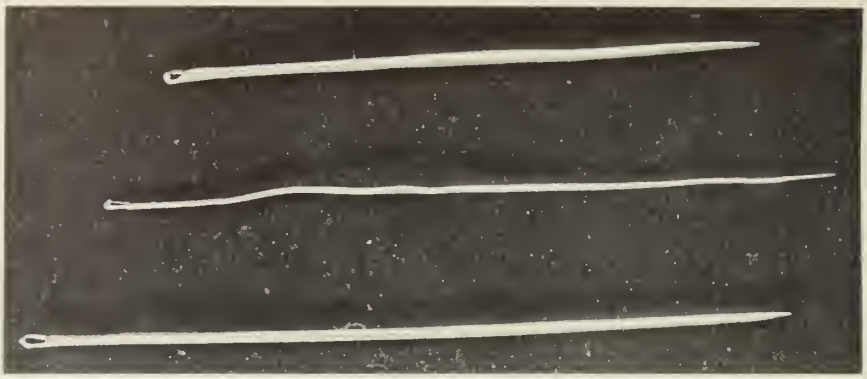
Pl. 40 Detail of necklace of Pl. 39.

Pl. 41 Left: broken stone mould with rosettes on both surfaces (*Cat.* 363, Reg. 1207) Colonial period. L. 9.0 cm; Dia. of larger rosette 4.6 cm. Right: bronze mould section (*Cat.* 362, Reg. 1198). Colonial period. L. 4.3 cm; greatest W. 5.0 cm (Note: in *Catalogue,* numbers with illustrations are reversed.)

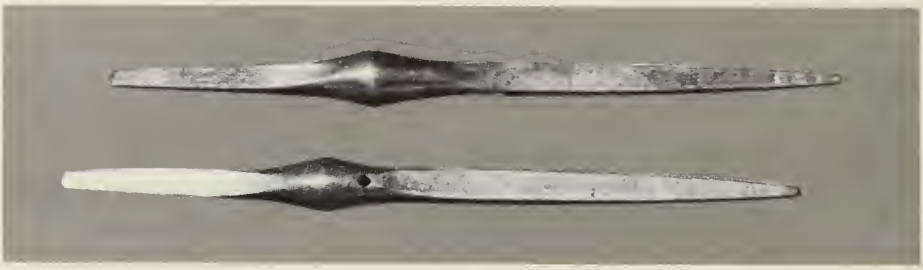


Pl. 42a Radiograph of tip of copper needle, showing structure. Magnification 80×.

Pl. 42b Detail of eye of copper needle. Magnification 12×.

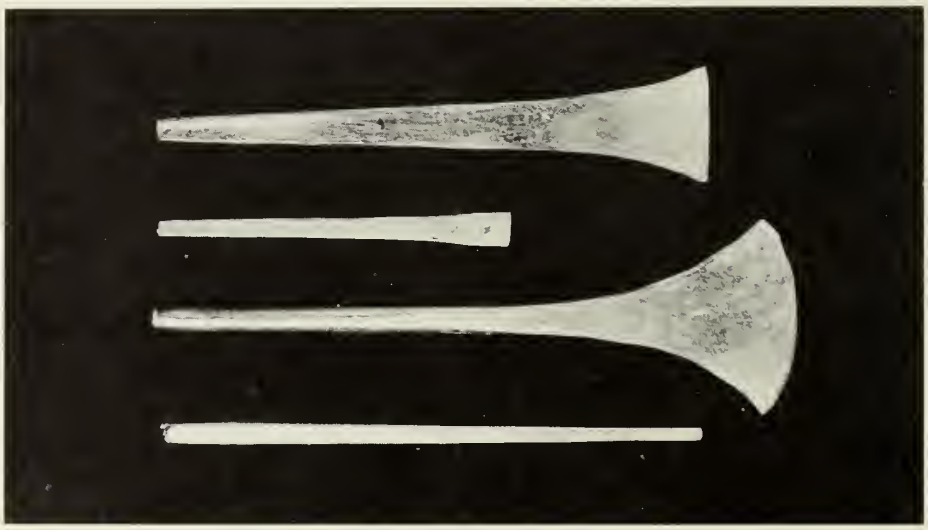


Pl. 43 Gold needles (*Cat*. 67, 68; Reg. 2407, 2408). Mochica (Frias).

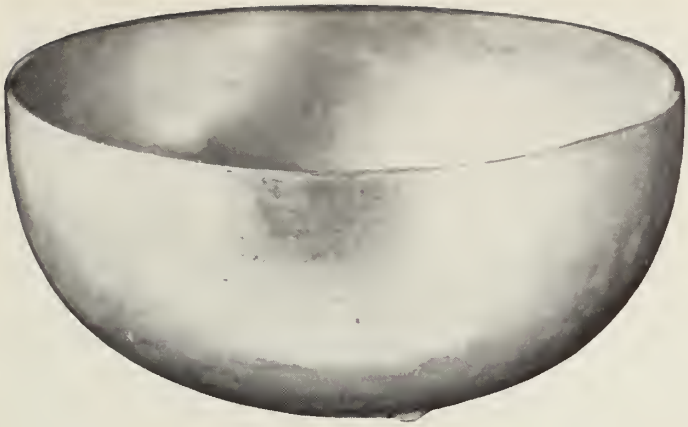


Pl. 44 "Spindles" (*Cat*. 196, 197; Reg. 2970, 2971). Chimu? L. 17.5 and 17.3 cm.

Pl. 45 Radiograph of "spindle" (*Cat*. 196, Reg. 2970).



Pl. 46 Gold spatulas and gravers (*Cat*. 69, 70, 71, 72; Reg. 2411, 2412, 2413, 2414). Mochica (Frias). Lengths (from top to bottom): 12.7 cm, 10.5 cm, 11.0 cm, 6.8 cm.



Pl. 47 Gold bowl (*Cat.* 95, Reg. 4561). Mochica (Frias). Dia. 13.5 cm.

Pl. 48 Beaker (*Cat.* 146, Reg. 4585). Chimu. H. 25.9 cm; Dia. of rim 20.0 cm.

Pl. 49 Vessel in form of a bird (*Cat*. 151, Reg. 4631). Chimu? L. 18.1 cm; H. 15.2 cm.

Pl. 50 Tall beaker with double bottom and applied plaques of turquoise or chrysocolla (*Cat*. 148, Reg. 4608). Chimu. H. 13.2 cm; Dia. of rim 8.0 cm.

Pl. 51 Beaker of Pl. 50. Detail inside rim.

Pl. 52 Beaker of Pl. 50. Detail of double bottom.

Pl. 53 Double-spouted, bridge-handled vase (*Cat.* 205, Reg. 4630). Chimu, Lambayeque style. H. 23.0 cm; W. 23.2 cm.

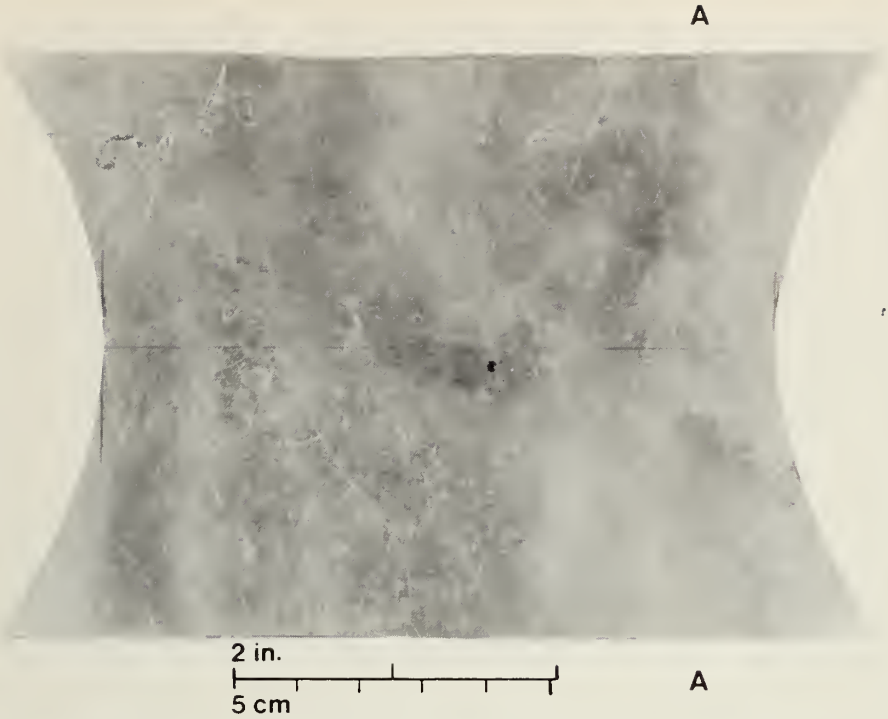
Pl. 54 Detail of crimping at widest diameter of vase of Pl. 53.

Pl. 55 Waisted crown (*Cat*. 159, Reg. 3061). Chimu. H. 19.0 cm.

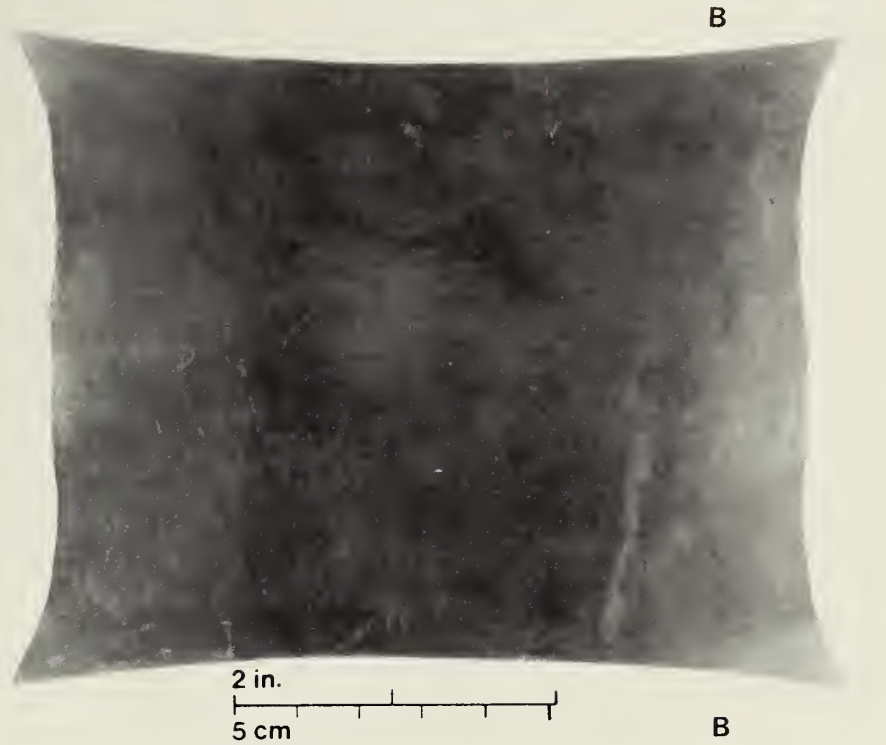
Pl. 56 Detail of crown of Pl. 55; lower part of crown, interior.

Pl. 57 Detail of crown of Pl. 55; upper part of crown, exterior.

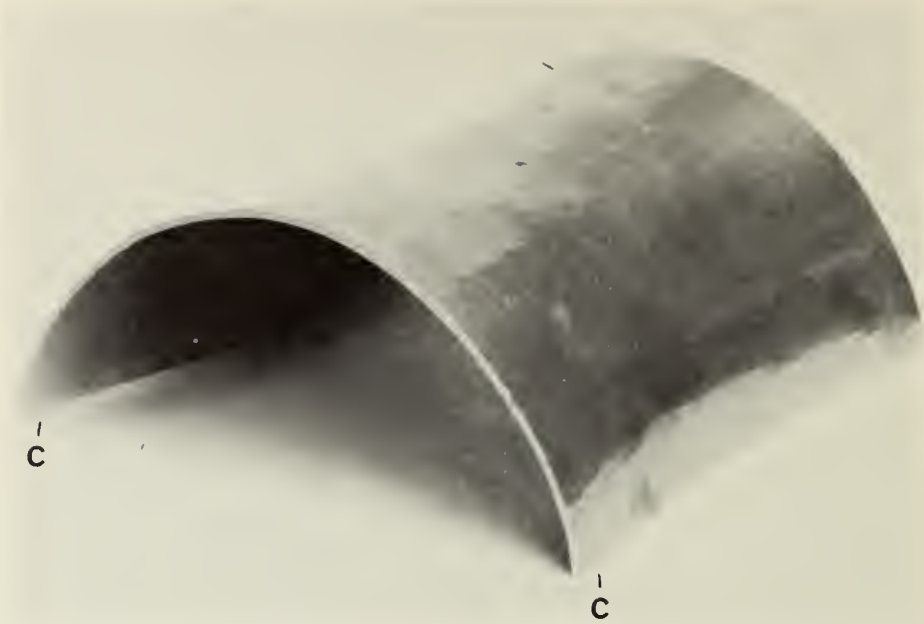
Pl. 58 Waisted crown (*Cat.* 161, Reg. 2215). Chimu. H. 19.5 cm; Dia. 19.0 cm.



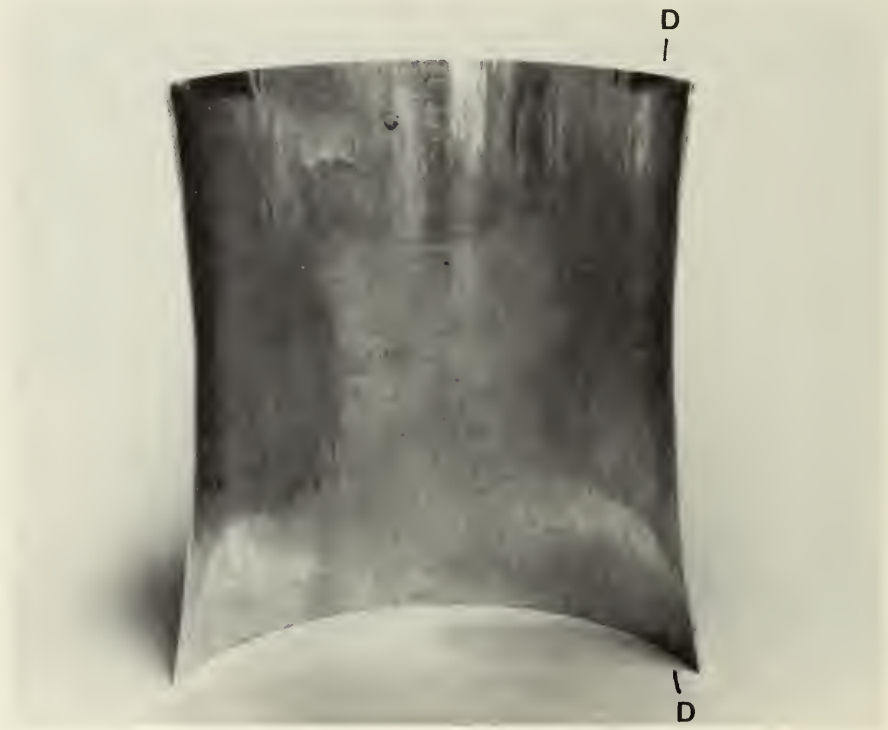
Pl. 59 Sheet of pewter with ends cut in form of arcs. Section of sheet A–A, Fig. 1.



Pl. 60 Sheet after hammering along centre line. Section of sheet B–B, Fig. 1.



Pl. 61 Sheet after trimming, to form once more a regular rectangle, and after hammering of edges, to create a waisted half cylinder. Section of lower and upper edges C–C, Fig. 1.



Pl. 62 Half cylinder, as Pl. 61 showing section in the vertical line, D–D, Fig. 1.

Pl. 63 Jaguar (*Cat*. 19, Reg. 2514). Probably early Mochica. L. 10.3 cm. See also Pl. 69 and 70.

Pl. 64 Gloves (*Cat*. 185, 186; Reg. 1902, 1903). Chimu, Lambayeque style. L. 53.9 and 54.6 cm.

Pl. 65 Conch shell in gold sheet (*Cat.* 149, Reg. 2904). Chimu? L. 17.4 cm.

Pl. 66 Ornamental end of digging-stick (*Cat.* 226, Reg. 1896). Chimu, Lambayeque style. L. 247.0 cm.

Pl. 67 Llama (*Cat*. 269, Reg. 3224). Inca. H. 2.5 cm; L. 2.4 cm. Magnification ca 4.75×.

Pl. 68 Radiograph of llama of Pl. 67. Magnification ca 4.25×.

Pl. 69 Radiograph of jaguar of Pl. 63, from the side.

Pl. 70 Radiograph of jaguar of Pl. 63, from below.

Pl. 71 Nose ornament (*Cat.* 34, Reg. 3327). Vicus. H. 7.7 cm; W. 9.4 cm.

Pl. 72 Radiograph of nose ornament of Pl. 71.

Pl. 73 Nose ornament (*Cat.* 45, Reg. 3362). Vicus. H. 5.7 cm; W. 7.8 cm. Note: diagonal lines represent wires securing the ornament to three pins for display.

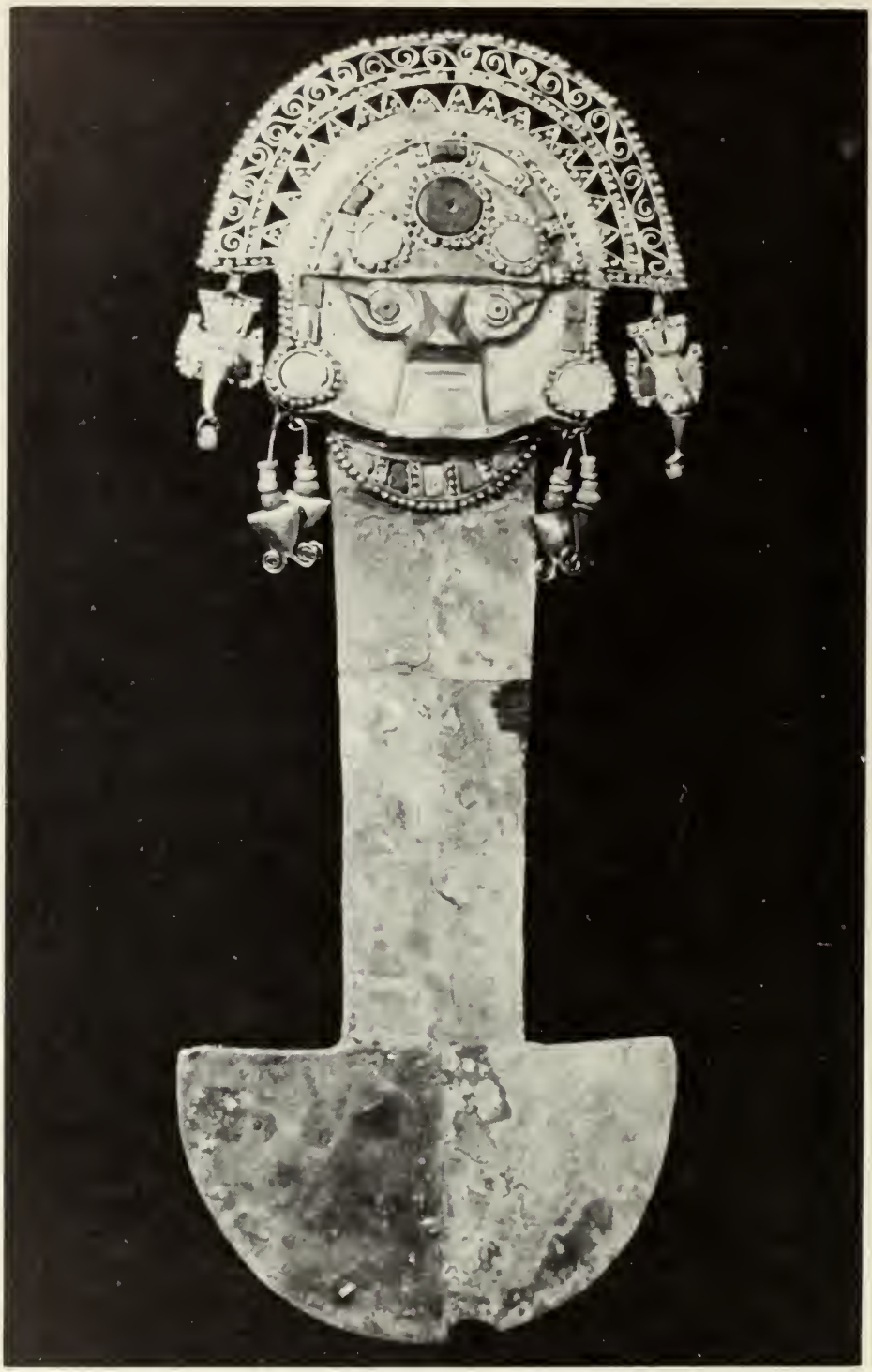
Pl. 74 Radiograph of nose ornament of Pl. 73.

Pl. 75 Nose ornament (*Cat.* 42, Reg. 3361). Vicus. H. 11.0 cm; W. 17.0 cm. Note: photograph depicts ornament as displayed.

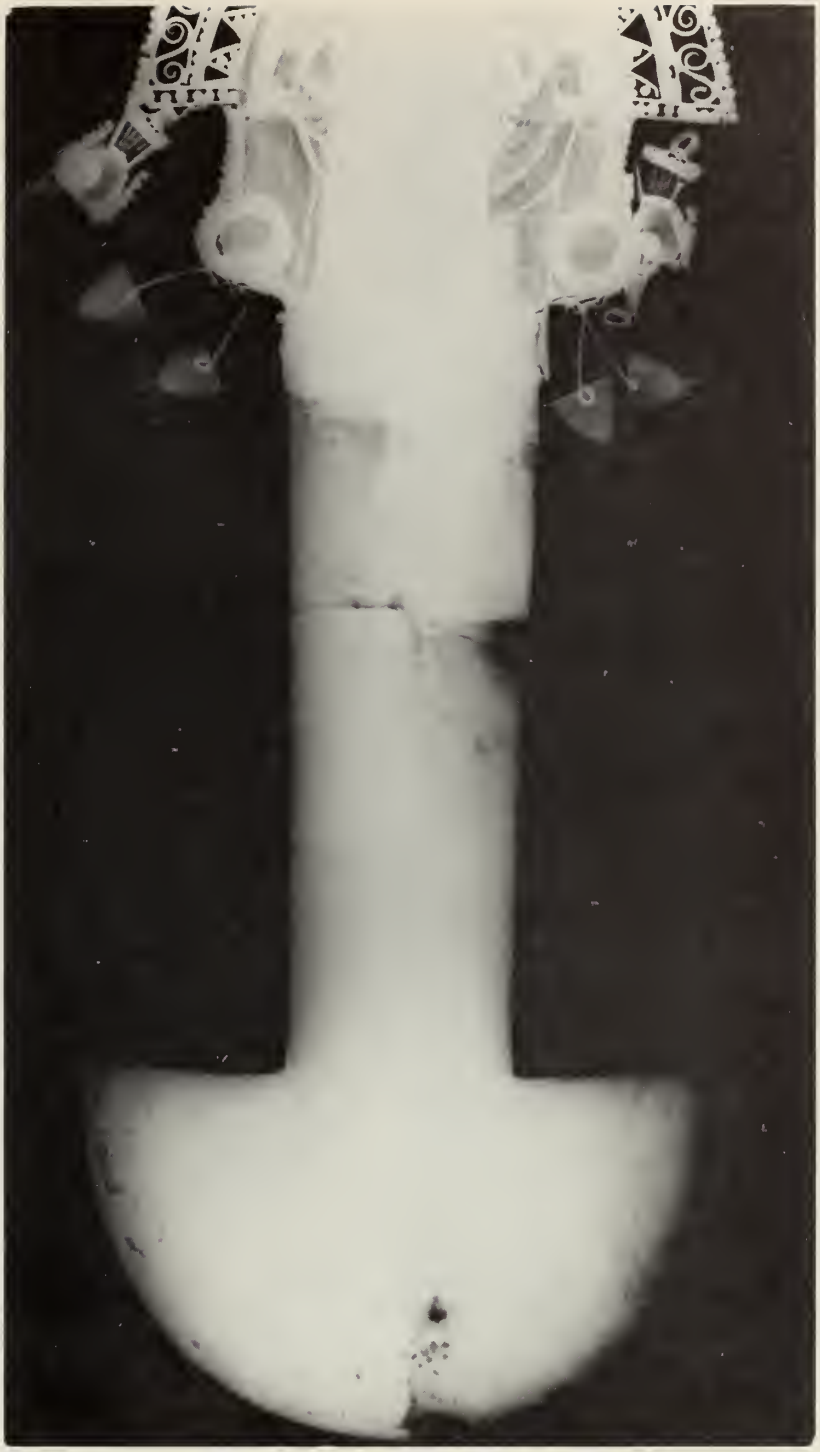
Pl. 76 Radiograph of nose ornament of Pl. 75.

Pl. 77 Detail of reverse of lower part of nose ornament of Pl. 75 showing, in centre, tongue of adhesive and its shadow. Magnification ca 4.5×.

Pl. 78 Detail of tongue of adhesive shown in Pl. 77 and the corrosion products covering part of the adhesive. Magnification ca 9×.



Pl. 79 Ritual knife (*tumi*) (*Cat*. 227, Reg. 2708). Chimu, Lambayeque style. H. 27.7 cm; W. 10.3 cm.

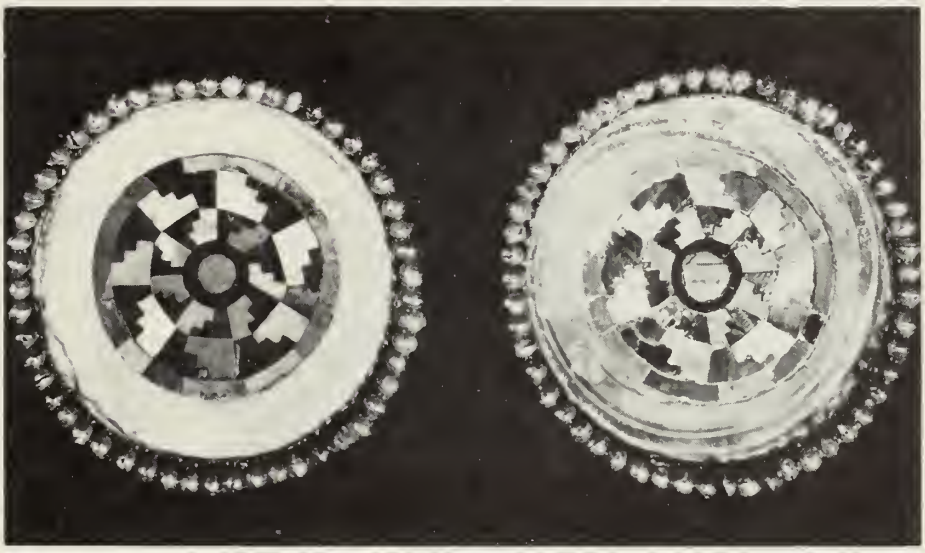


Pl. 80 Radiograph of *tumi* of Pl. 79, showing blade, shaft, and part of finial.

Pl. 81 Jar of gold-surfaced alloy (*Cat.* 259, Reg. 4670). Inca. H. 10.5 cm.

Pl. 82 Radiograph of jar of Pl. 81.

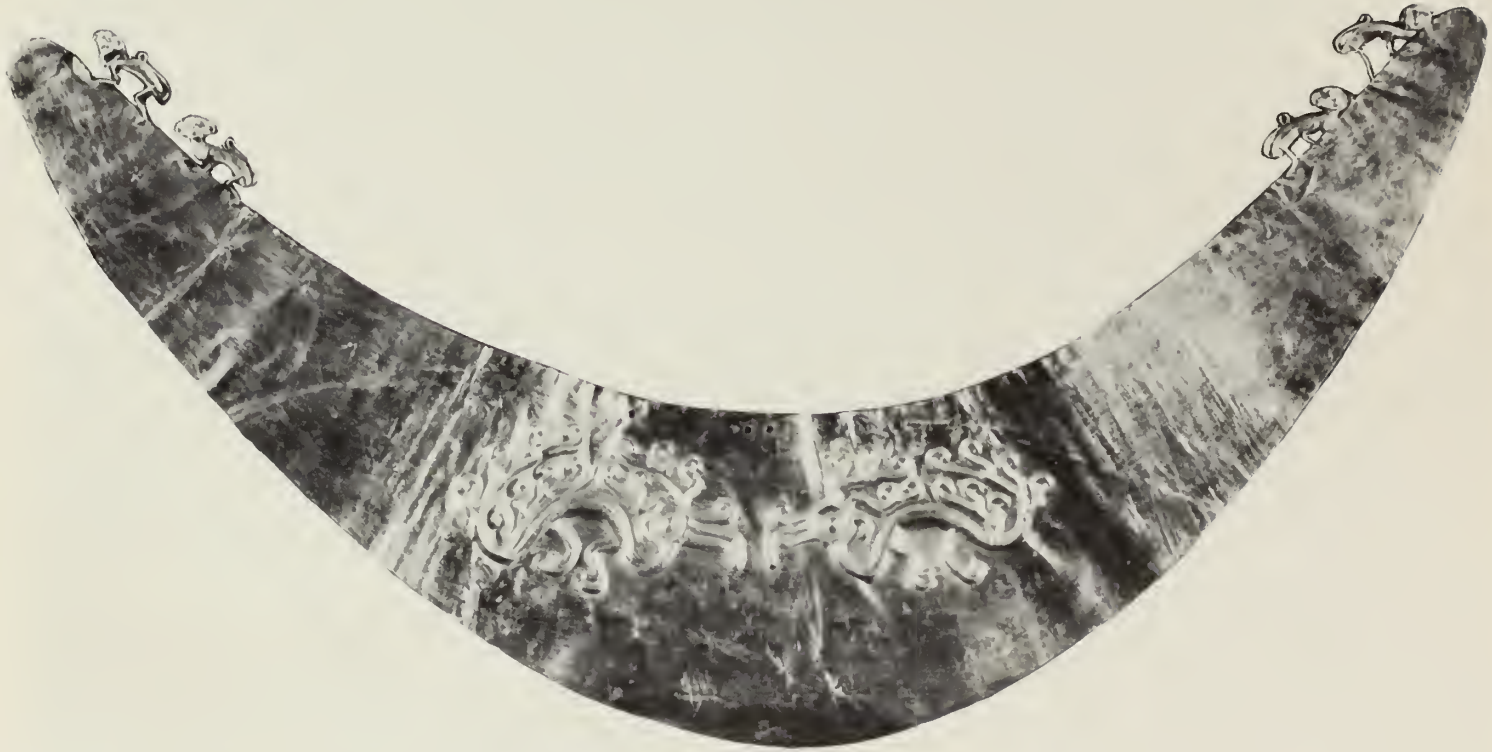
Pl. 83 Radiograph of jar of Pl. 81 showing strap handles.



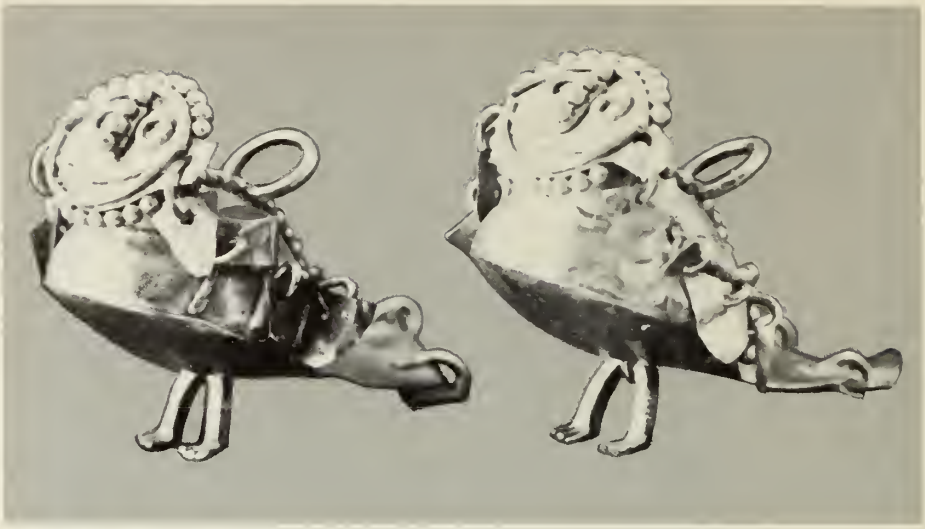
Pl. 84 Pair of ear ornaments (*Cat.* 224, 225; Reg. 1884, 1885). Chimu. Dia. 6.8 cm.

Pl. 85 Spider (*Cat.* 59, Reg. 3889). Vicus. L. of body 4.0 cm.

Pl. 86 Pendant (*Cat.* 63, Reg. 2513). Mochica (Frias). H. 3.4 cm; W. 4.2 cm.

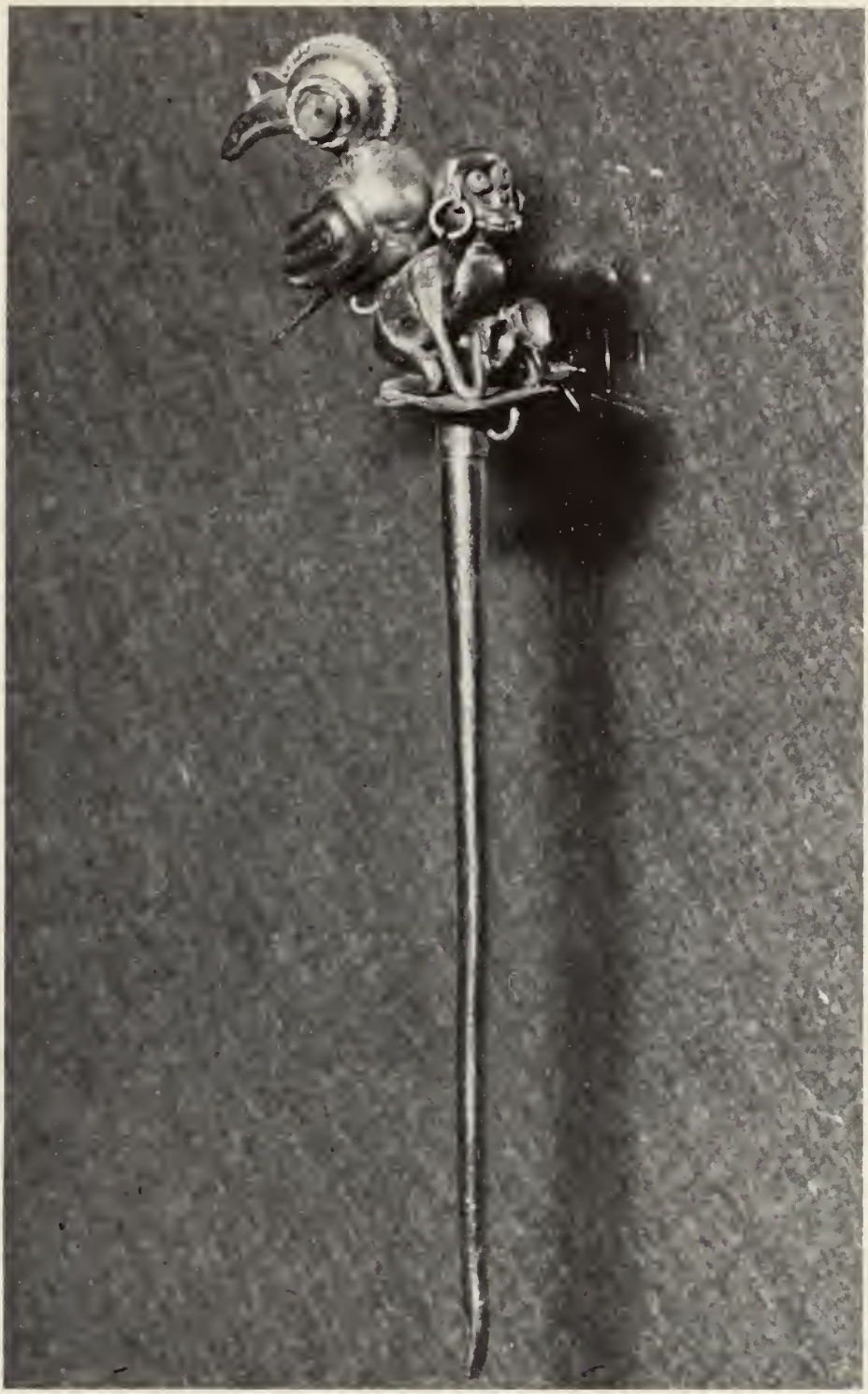


Pl. 87 Pectoral (*Cat*. 82, Reg. 2716). Mochica (Frias). L. 46.5 cm.



Pl. 88 Pair of pendants (*Cat.* 87, 88; Reg. 2520, 2521). Mochica (Frias). H. 3.2 cm; W. 4.0 cm.

Pl. 89 Small anthropoid figure on serpent's head (*Cat.* 100, Reg. 2344). Mochica (Frias).



Pl. 90 Pin with a stylized bird mounted on the back of a monkey (*Cat.* 96, Reg. 2508). Mochica (Frias). H. 15.6 cm.

Pl. 91 Pendant (*Cat*. 103, Reg. 2679). Mochica (Frias). H. 4.0 cm; W. 6.2 cm.

Pl. 92 Anthropomorphic mask (*Cat*. 54, Reg. 2213). Vicus. H. 9.8 cm; W. 10.5 cm.

Pl. 93 Feline head (*Cat.* 55, Reg. 2216). Vicus. H. 8.0 cm; W. 10.7 cm.

Pl. 94 Nose ornament (*Cat.* 33, Reg. 3367). Vicus. H. 7.0 cm; W. 9.4 cm.

Pl. 95 Nose ornament (*Cat.* 35, Reg. 3558). Vicus. H. 5.7 cm; W. 9.4 cm.

Pl. 96 Nose ornament (*Cat.* 36, Reg. 3560). Vicus. H. 5.5 cm; W. 7.3 cm.

Pl. 97 Nose ornament (*Cat*. 38, Reg. 3687). Vicus. H. 3.8 cm; W. 7.7 cm.

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